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# ENGINE EXPERIMENTS WITH FIRE SAFE FUELS

**FINAL REPORT**
**AFLRL NO. 31**


by

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A single-cylinder research engine (CLR) was operated on diesel fuel containing a halon compound, bromochloromethane, added to the fuel at 5 percent by volume as a fire safe fuel additive. Basic diesel power comparisons were made using diesel fuel and diesel fuel plus additive. A series of experiments were then conducted to investigate injection system variables, including injector camshaft profile, barrel and plunger diameter, injection nozzle configuration, and nozzle hole size, in an effort to recover power losses noted when using the diesel fuel plus additive blend.

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# I. INTRODUCTION

There is an acknowledged need for the development of fuels which will burn satisfactorily in engines but will not burn as a result of enemy attack on combat vehicles. The availability of such a fuel would not only reduce vehicle vulnerability resulting in a saving of lives, but would also provide for significant weight savings due to reduction in armor surrounding the vehicle fuel tank system. One approach currently being investigated involves using halogenated hydrocargons and is principally a result of research done by the Terminal Ballistics Laboratory at the Ballistics Research Labs. Initial research was conducted on diesel fuel containing dibromomethane and vulnerability results indicated significant reductions in fires when dibromomethane up to 10 percent vol was added to the fuel. Following the initial vulnerability experiments, the treated fuel was evaluated in a single cylinder research engine (CFR) and a six cylinder production engine (Cummins) for performance and possible materials degradation. CFR engine results showed there to be no significant effects on fuel ignition quality. Work with the Cummins engine showed there to be a significant decrease in power output (predicted by the decrease in Btu) although the engine was responsive throughout the speed and load range. Additionally, some attack of combustion products on engine materials was noted.*

Continued research for the best type material to achieve maximum vulnerability reduction resulted in a change from dibromomethane to a mixture of materials containing approximately 85 wt percent bromochloromethane, 10 wt percent methylene chloride, and 5 wt percent methylene bromide (referred to as BCM). Gunfire tests indicated a good measure of fire safety when 5 percent of this mixture was added to diesel fuel. However, the following questions remained to be answered:

- How would diesel fuel + 5 percent bromochloromethane respond in diesel engines?
- What is the composition of the exhaust and what affect might this have on human, animal, and plant life?
- What are the flammability limits of bromochloromethane when blended into diesel fuel?

Since answers were not readily available from prior research or previously compiled data, these questions formed the basis for the research work described in this and companion reports.

*USAFLRL Letter Report to TBL, 6 November 1972, Subj: Evaluation of Diesel Fuel Containing Dibromomethane (Contract DAAD05-72-C-0410).

## II. SUMMARY AND CONCLUSIONS

A series of experiments were performed in a single cylinder research engine using diesel fuel and diesel fuel plus 5 vol percent bromochloromethane in order to determine the response of the fuel blend to changes in injection system parameters. Initial baseline data showed a decrease in power for BCM-containing fuel run under the same conditions as diesel fuel. When run at diesel power, there was a significant decrease in efficiency. A series of experiments was then conducted to investigate injection system variables including camshaft profile, barrel and plunger diameter, injection nozzle configuration, and nozzle hole size. Part load performance was also evaluated. From these experiments, the following was concluded:

- Open chamber diesel engines can be modified to perform satisfactorily on diesel fuel plus 5 percent BCM (satisfactorily defined as diesel power) and no greater than 9.4 percent increase in fuel consumption on a mass basis.

- Diesel fuel plus 5 percent BCM responds basically the same as neat diesel fuel to changes in the fuel-air mixing parameters. However, diesel fuel plus 5 percent BCM is more sensitive to changes than neat diesel fuel.

- Presence of 5 percent BCM has no deleterious effect on the ignition delay period.

- The data indicate there to be no chemical inhibition of the combustion process due to the presence of 5 percent BCM. The treated fuel burns like a diesel fuel, although more Btu input is required to overcome the heat capacity of the BCM.

- Differences in the combustion events between diesel fuel and the treated fuel can be explained by the differences in viscosity, density, and volatility which affect the injected spray pattern.

## III. PROGRAM PLAN AND OBJECTIVES

Following the engine runs with dibromomethane, questions arose concerning the type of changes which would have to be made to an engine in order to achieve diesel fuel power levels and still maintain reasonable fuel economy. As a result, the decision was made to conduct a combustion study of diesel fuel treated with 5 percent BCM in a single cylinder research engine. The principle objective would be to determine the response of the fuel blend to changes in injection system parameters in order to establish guidelines under which full scale engines could be modified to achieve satisfactory performance on diesel fuel + BCM. A secondary objective was to determine the mechanism of combustion inhibition of bromochloromethane in diesel fuel.

## IV. PROGRAM DETAILS

### A. Fuel Properties

The physical and chemical properties of the base diesel fuel and treated fuel are compared in Table 1. The base fuel was a reference diesel fuel (Cat 1-H) used for oil testing with properties typical of No. 2 diesel fuels. The specification under which the fuel is procured is quite narrow and closely controlled, and significantly reduces the batch to batch variations. Therefore, the property control of the test fuel was insured throughout the duration of the program. The bromochloromethane was added at 5 percent by volume to the base fuel. The particular properties whose differences may affect the spray and combustion process are compared in Table 2. Addition of bromochloromethane increased the density while significantly decreasing the viscosity. The heat content was decreased on a mass basis that is a total of 9.4 percent for the test fuel with 5 percent bromochloromethane and 4.5 percent on a volume basis. Additionally, the boiling range of bromochloromethane is approximately 105° to 200°F, whereas, the initial boiling point of the base diesel fuel is approximately 410°F. Therefore, there are significant heat content and physical property differences between the two fuels which would not only account for a difference in power output, but could also result in a significant spread in injection system and spray performance.

TABLE 1. NEAT AND TREATED FUEL PROPERTIES

| Property | Neat Diesel Fuel(Cat 1-H) | Diesel Fuel +5% BCM |
|---|---|---|
| Density | 0.86 | 0.90 |
| Viscosity at 100°F | 3.40 | 2.56 |
| Flash Point, °F | 185 | +230 |
| Cloud Point, °F | +23 | |
| Pour Point, °F | +18 | |
| Water & Sediment | 0 | |
| Carbon Residue, % | 0.10 | – |
| Lamp Sulfur, % | 0.415 | – |
| Acid No. | 1.08 | |
| Aniline No., °F | 145 | |
| Copper Corrosion | 1A | |
| Distillation, °F | | – |
| IBP | 410 | 140 |
| 10% | 468 | 445 |
| 50% | 519 | 520 |
| 90% | 603 | 601 |
| EP | 689 | 675 |
| Cetane No. | 47 | |
| Heat of Combustion, BTU/lb | 19,550 | 17,673 |

TABLE 2. FUEL VARIABLES MOST SIGNIFICANT TO SPRAY AND COMBUSTION

| | Density | BTU/Lb | BTU/Gal | Vis,cs | Boiling Range,°F |
|---|---|---|---|---|---|
| Diesel Fuel (Cat 1-H) | 0.86 | 19,500 | 139,483 | 3,40 | 410 -689 |
| W/5% BCM | 0.90 | 17,672 | 133,145 | 2.56 | 140 -675 |

TABLE 3. CLR OPEN CHAMBER ENGINE

| | |
|---|---|
| Bore | 3.80 in. |
| Stroke | 3.75 in. |
| Displacement | 42.5 in³ |
| Compression Ratio | 16.5:1 |
| Valve Timing (In) | 18° BTDC–58° ABDC |
| (Ex) | 124° ATDC–20° ATDC |
| | 38° Overlap |

### B. Engine Parameter Investigation

#### 1. Description of Engine

The engine chosen for this phase of research was the cooperative lubricants research (CLR) open-chamber diesel engine manufactured by the Laboratory Equipment Corporation (LABECO). Engine characteristics are shown in Table 3. Of particular interest is the relatively non-typical valve overlap of 38° as compared to a more normal 4 or 5°. By way of explanation, LABECO has developed a widely used spark-ignition CLR

engine and has done very little development on the diesel version. Many parts of the two engines, including the camshaft, are interchangeable. Therefore, the overlap normally associated with spark ignition engines was also found on the diesel version. The overlap, combined with the relatively low (for an engine of this displacement) 16½ to 1 compression ratio, results in relatively anemic performance under best diesel conditions, but still provides an adequate research tool for comparing the relative combustion performance of fuels. The combustion chamber utilizes a deep, small diameter cup in the piston into which the fuel spray is directed (Figure 1). Additionally, a shrouded intake valve is used to control air swirl in the chamber.

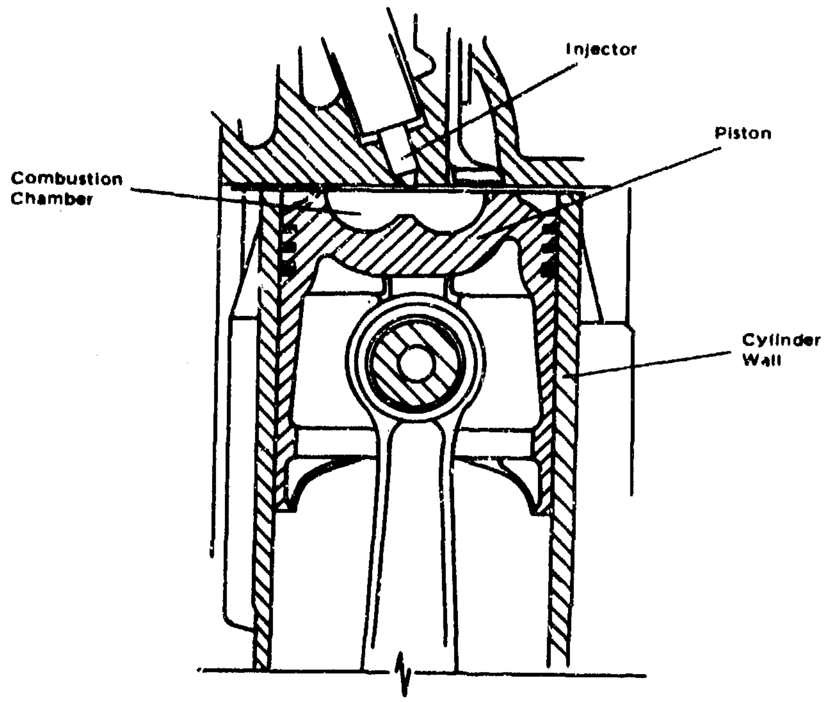



FIGURE 1. CLR OPEN CHAMBER ENGINE (HALF SIZE)

### 2. Baseline Data

Initial runs were conducted to obtain baseline data on the reference diesel fuel as well as preliminary data on diesel fuel containing 5 percent BCM. These results are shown in Figure 2 along with the engine conditions (Table 4) in which indicated horsepower and indicated specific fuel consumption are plotted versus engine speed. These data represent best power timing for diesel fuel at No. 5 to No. 7 smoke level (Robert Bosch). Then the treated fuel (diesel + 5 percent BCM) was run under conditions identical to the diesel fuel. A lower horsepower curve was the result. Additionally, there was a decrease in efficiency as

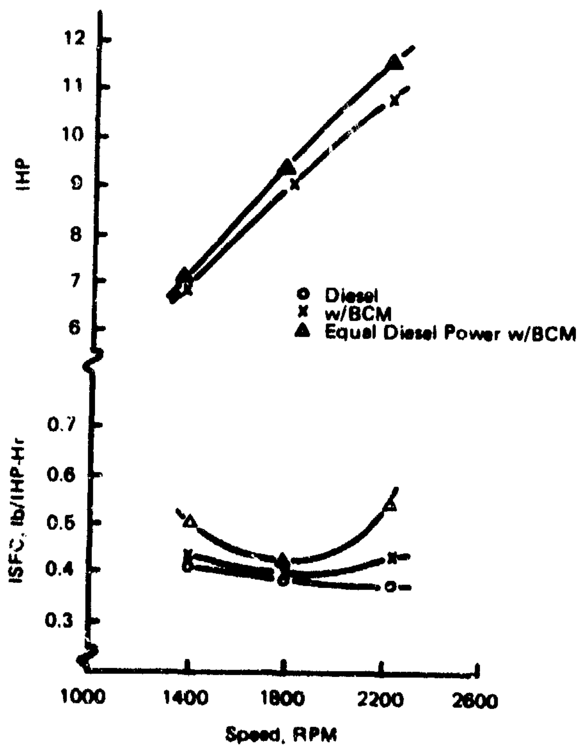



FIGURE 2. BASELINE RESULTS

TABLE 4. BASELINE COMPARISON

Nozzle: NL-141
4 Hole
0.0098-in. Dia.
$3.02 \times 10^{-4}$ in$^2$ Area

Camshaft: Basic Metric

Plunger Dia: 10 mm

| Engine Speed, RPM | | Nozzle Opening: 2500 psi | |
|---|---|---|---|
| | 1400 | 1800 | 2200 |
| Diesel Fuel — Indicated Horsepower | 7.0 | 9.0 | 11.0 |
| Diesel Fuel — ISFC, lb/IHp-hr | 0.419 | 0.389 | 0.377 |
| Diesel Fuel + 5% BCM, Diesel Conditions — Indicated Horsepower | 6.8 | 8.6 | 10.6 |
| Diesel Fuel + 5% BCM, Diesel Conditions — ISFC, lb/IHp-hr | 0.464 | 0.394 | 0.447 |
| Diesel Fuel + 5% BCM, Diesel Power — Indicated Horsepower | 7.0 | 9.0 | 11.0 |
| Diesel Fuel + 5% BCM, Diesel Power — ISFC, lb/IHp-hr | 0.506 | 0.427 | 0.541 |

indicated by the higher ISFC for the treated fuel. Therefore, under identical engine conditions, both a decrease in power and efficiency were noted with the bromochloromethane containing fuel. The final set of baseline data was obtained by increasing the flow rate of fuel with BCM so that the same power, as indicated with diesel fuel, was obtained. Under these conditions, the indicated specific fuel consumption was the primary comparative criteria, and as illustrated in Figure 2, there was a decrease in efficiency ranging from 10 to 40 percent with the greatest difference shown at higher speeds.

### 3. Criteria and Test Procedures

As a result of the data obtained during the baseline evaluations, a procedure was established in which the primary criteria for comparing performance of fuels (with and without BCM) would be engine efficiency in terms of ISFC. This procedure involved operating at 1400, 1800, and 2600 rpm (the indicated horsepower level obtained during the baseline runs). Best power timing would be established for each fuel and each set of injection system variables and fuel rate determined. Therefore, power would be the independent variable and fuel rate or efficiency would be the dependent variable. Satisfactory performance for this series of experiments was defined as horsepower equal to diesel performance with the best specific fuel consumption possible over the range of variables investigated. Based on the difference in heat content between diesel fuel and diesel fuel + 5 percent BCM, a decrease in ISFC of 9.4 percent would represent equal Btu utilization.

### 4. Experimental Results

The experimental program involved an investigation of the injection system variables shown in Table 5. Time did not permit a full factorial matrix of experiments, therefore, runs were selected to provide the following comparisons:

a. *Camshaft Profile Effect*

4 Hole Nozzle ($3.02 \times 10^{-4}$ in$^2$) Area; 10 mm barrel and plunger
Slow Rate vs Fast Rate

b. *Barrel & Plunger*

4 Hole Nozzle – 10 mm vs 7 mm
5 Hole Nozzle – 10 mm vs 7 mm

c. *Nozzles*

(1) **Effect of Number of Holes (Total Area Equal)**

10 mm B&P – 4 Hole ($3.02 \times 10^{-4}$ in$^2$) vs

6 Hole ($2.94 \times 10^{-4}$ in$^2$)

7 mm B&P – 5 Hole ($2.45 \times 10^{-4}$ $in^2$) vs

3 Hole ($2.26 \times 10^{-4}$ $in^2$)

(2) **Effect of Total Area (Number of Holes Equal)**

10 mm **B&P – 4 Hole $3.02 \times 10^{-4}$ $in^2$ vs $5.23 \times 10^{-4}$ $in^2$)**

In all cases, runs with diesel fuel and diesel fuel with bromochloromethane were made back to back. Duplicate runs were made with several of the variables when data appeared questionable and a part load analysis was conducted to verify full load results. Additionally, combustion data were obtained on most of the runs. Heat release data were calculated from the pressure time diagrams for analysis of events during the combustion expansion parts of the cycle. The engine performance and combustion data are contained in Appendix I and heat release data in Appendix II. The results of each of the performance comparisons were as follows:

TABLE 5. DESCRIPTION OF INJECTION SYSTEM VARIABLES

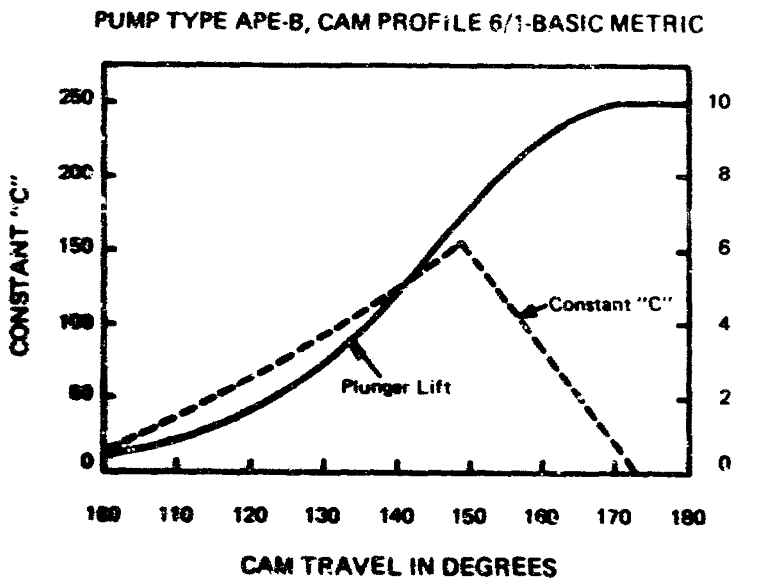
| | | | |
|---|---|---|---|
| **Camshaft** | | | |
| Slow Acceleration Rate | | | |
| Fast Acceleration Rate | | | |
| **Nozzles** | | | |
| 3 Hole | 0.0098 In. Diameter | $2.26 \times 10^{-4}$ $in^2$ Total Area | (123) |
| 4 Hole | 0.0098 In. Diameter | $3.02 \times 10^{-4}$ $in^2$ Total Area | (141) |
| 4 Hole | 0.0129 In. Diameter | $5.23 \times 10^{-4}$ $in^2$ Total Area | (537) |
| 5 Hole | 0.0079 In. Diameter | $2.45 \times 10^{-4}$ $in^2$ Total Area | (6961) |
| 6 Hole | 0.0079 In. Diameter | $2.94 \times 10^{-4}$ $in^2$ Total Area | (6969) |
| **Barrel and Plunger** | | | |
| 7 mm | | | |
| 10 mm | | | |

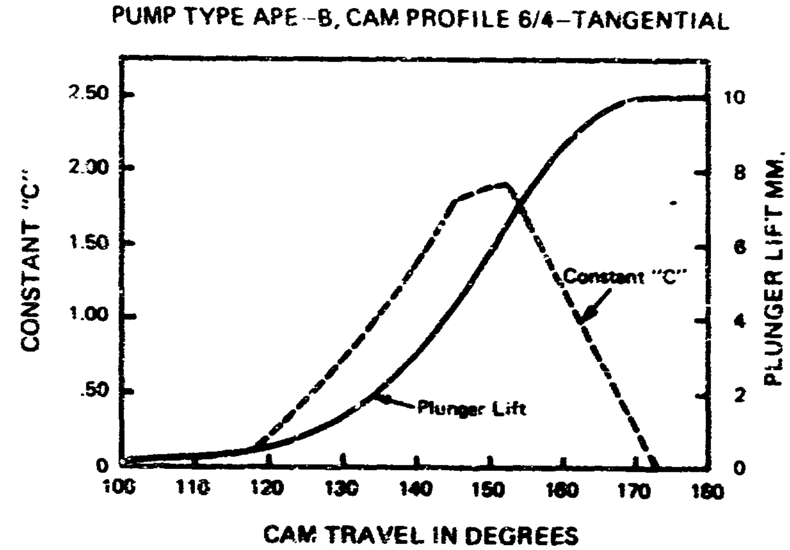
(3) **Effect of Injection Pump Camshaft Profile**

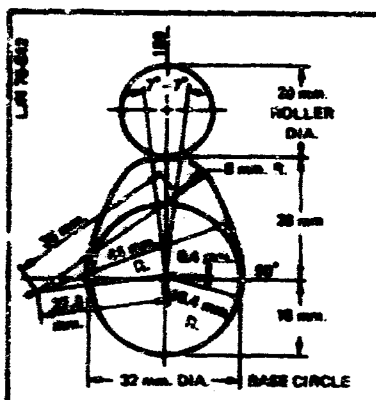
The two profiles investigated are characterized by the curves and data supplied by American Bosch in Figures 3 and 4.

The basic metric camshaft, which is standard with the CLR diesel engine, provides a relatively low acceleration rate, whereas the tangential cam is a fast acceleration cam resulting in higher instantaneous plunger velocity during the initial part of the delivery stroke. The relative effect of camshaft acceleration rate is illustrated by the comparisons with diesel fuel and diesel fuel + 5 percent BCM in Figure 5. As previously stated, all data were obtained at the same power setting, therefore, efficiency, in terms of indicated specific fuel consumption, is the primary comparative criterion. The effect of the injection system variable on diesel fuel performance is shown at the top of the figure and on diesel fuel + 5 percent BCM at the bottom of the figure. Therefore, diesel fuel performance can be compared as a function of the injection system variable as well as compared to the performance of diesel fuel + bromochloromethane. For this comparsion, the 10 mm barrel and plunger and 4 hole nozzle were utilized. The basic metric cam data was obtained during the baseline part of the evaluation so that data were obtained at only 3 speeds. The tangential camshaft data were obtained at the 4 speeds which will be carried through for the remainder of the comparisions.

Data compiled in Figure 5 indicate that diesel fuel performance, especially through the low and mid-range, was significantly improved with the higher acceleration profile although the difference in efficiency decreased at the higher speed. The treated fuel, on the other hand, performed significantly better with the higher injection rate throughout the speed range. The dif-



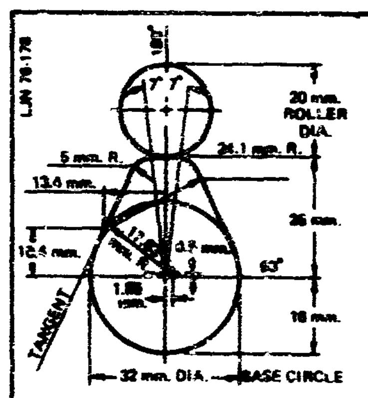




| PLG. DIA. mm. | LIFT TO P.C. mm. ±.20 | THEOR. BEG. OF DELIVERY AT PUMP OUTLET CONNECTION | | RE-TRACTION VOLUME cu. mm. |
|---|---|---|---|---|
| | | LIFT mm. ±.20 | CAM DEG. | |
| 6 | 2.80 | 4.25 | 137.5 | 50 |
| 6.5 | 2.80 | 4.00 | 138.0 | 50 |
| 7 | 2.80 | 3.80 | 138.0 | 50 |
| 7.5 | 2.75 | 3.90 | 135.5 | 50 |
| 8 | 2.75 | 3.75 | 134.5 | 50 |
| 8.5 | 2.75 | 3.65 | 134.0 | 50 |
| 9 | 3.00 | 3.80 | 135.0 | 50 |
| 10 | 3.00 | 3.85 | 134.0 | 50 |

INSTANTANEOUS PLUNGER VELOCITY
METERS/SECOND = $\frac{C \times RPM}{1,000}$

FIGURE 3. PLUNGER LIFT AND VELOCITY CHART




| PLG. DIA. mm. | LIFT TO P.C. mm. ±.20 | THEOR. BEG. OF DELIVERY AT PUMP OUTLET CONNECTION | | RE TRACTION VOLUME mm |
|---|---|---|---|---|
| | | LIFT mm. ±.20 | CAM DEG | |
| 6 | 2.80 | 4.25 | 144.5 | 50 |
| 6.5 | 2.80 | 4.50 | 143.5 | 50 |
| 7 | 2.80 | 3.80 | 143.0 | 50 |
| 7.5 | 2.75 | 3.90 | 143.0 | 50 |
| 8 | 2.75 | 3.75 | 142.5 | 50 |
| 8.5 | 2.75 | 3.85 | 142.0 | 50 |
| 9 | 3.00 | 3.90 | 143.0 | 50 |
| 10 | 3.00 | 3.86 | 142.0 | 50 |

INSTANTANEOUS PLUNGER VELOCITY
METERS/SECOND = $\frac{C \times RPM}{1,000}$

FIGURE 4. PLUNGER LIFT AND VELOCITY CHART

that the rate of injection, which controls rate of burning, is of greater significance with the BCM inhibitor in the fuel than for the reference diesel fuel itself. While this could be explained in terms of a chemical inhibition on rate of combustion, it could also be due to the effect on injected spray pattern and the need for injecting a greater quantity of fuel in order to achieve equal horsepower output. The analysis of the combustion event is discussed in more detail on page 15 of this report. As a result of these experiments, it was decided to conduct the remainder of the experimental program using the tangential camshaft.

#### (4) Effect of Plunger and Barrel Size

Two plunger and barrel diameters, 10 mm and 7 mm, were utilized to evaluate the effect of this variable. Data were obtained with two different nozzles, the 4 hole ($3.02 \times 10^{-4}$ sq in. total area) and 5 hole ($2.45 \times 10^{-4}$ sq in. total area). A comparison with the 4 hole tip is shown in Figure 6. The 4 hole tip and 10 mm barrel and plunger combination provided the best operating performance throughout all experiments for the diesel fuel + BCM. Changing to the 7 mm barrel and plunger, which would have the effect of decreasing the time rate of injection, resulted in a significant decrease in efficiency. A similar decrease in efficiency was noted at the lower speeds with diesel fuel. However, at the 2000 and 2400 rpm operating points, an improvement in efficiency with the 7 mm barrel and plunger was observed. This is believed to be a tradeoff between fuel-air mixing and rate of injection. At the lower speeds, the higher rate of diesel fuel injection with the 10 mm barrel and plunger provides better atomization and mixing, thus resulting in improved combustion. However, at the higher speeds, the injection rate with the 7 mm barrel and plunger is sufficient for adequate atomization and the slower rate of injection results in improved combustion control, therefore providing an improvement in efficiency. Analysis of the combustion data showed slightly advanced timing for the fuel with BCM compared with neat diesel, but approximately the same injection duration. There was no significant affect on ignition delay.

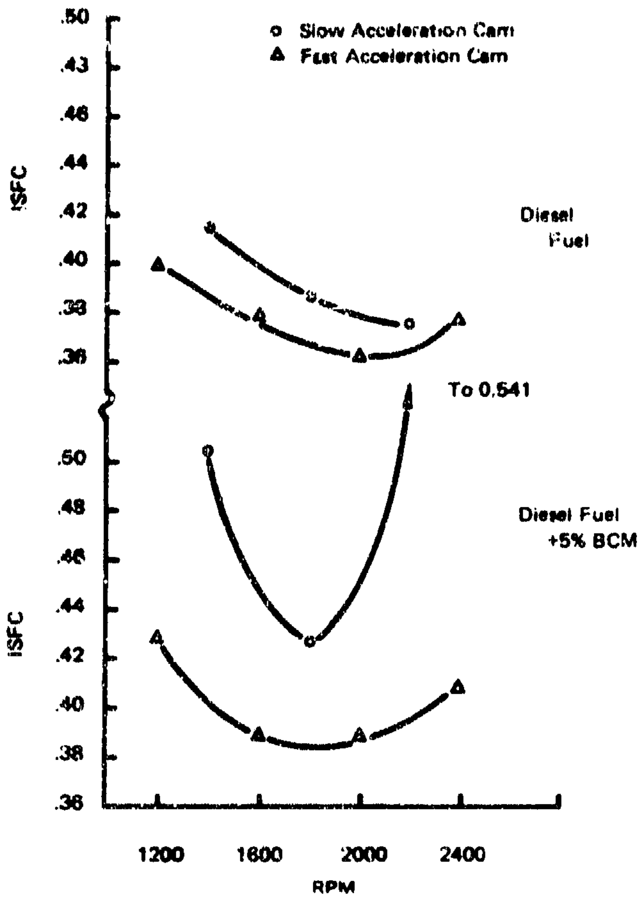



FIGURE 5. EFFECT OF CAMSHAFT
(10mm B&P 4-Hole Nozzle)

The performance comparison with the 5 hole tip is shown in Figure 7. Performance with the 5 hole tip for both diesel and BCM was poorer than with the 4 hole nozzle. However, again diesel fuel appeared less sensitive to injection rate than did diesel fuel + BCM. While there was a significant difference between the 7 and 10 mm performance with BCM, the difference in performance with diesel fuel was less pronounced. In fact, at all but the high speeds, the 7 mm barrel and plunger performed as well, if not better, than the 10 mm barrel and plunger. The high speed data were affected by the occurrence of multiple injections which were ultimately brought under control by increasing the nozzle opening pressure.

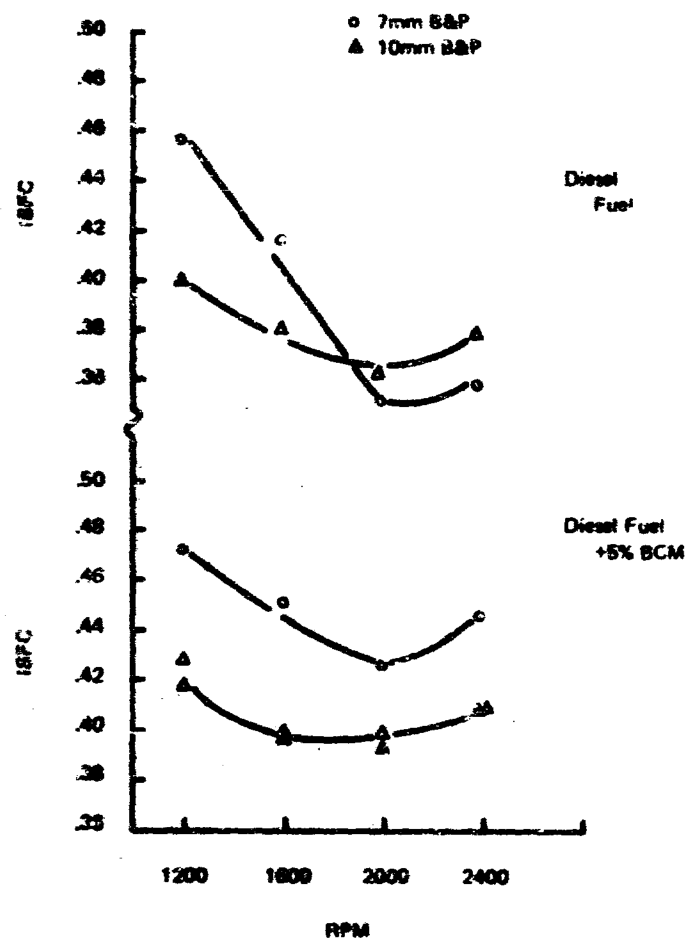



FIGURE 6. EFFECT OF BARREL & PLUNGER
(4-Hole Tip)

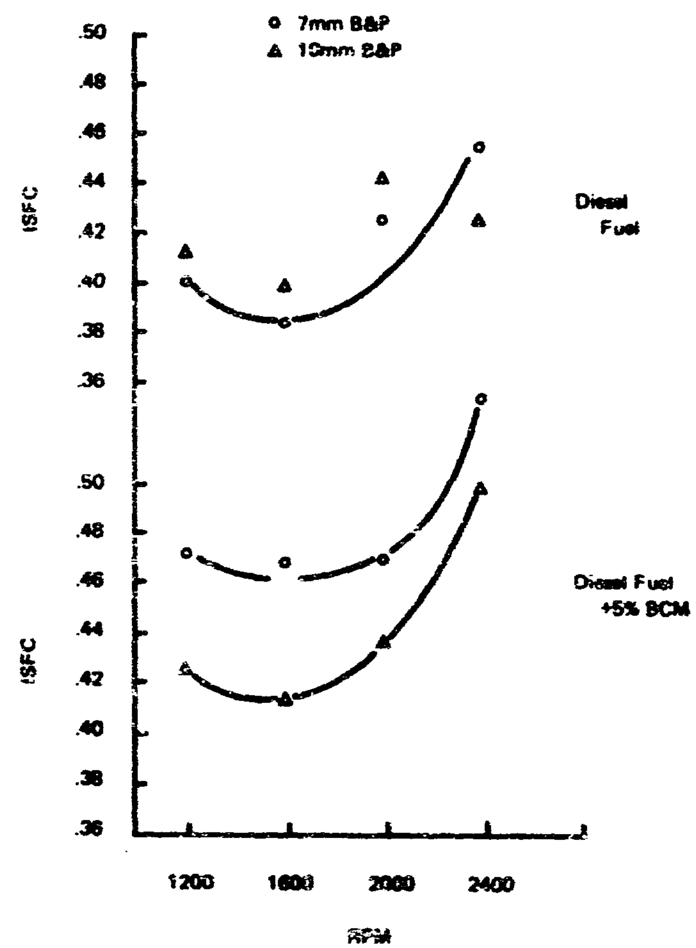



FIGURE 7. BARREL & PLUNGER EFFECT
(5-Hole Tip)

### (5) Effects of Nozzle Configuration

Three types of comparisons were made to observe the effect of nozzle configuration. Two sets of experiments were conducted with nozzles having approximately equal areas, but different number of holes. Then, a comparison was made with equal number of holes to determine the effect of total area. The results of these comparisons are as follows:

- *Effect of Number of Holes (Areas Equal)*

The first set of experiments was conducted with a 5 hole nozzle of $2.45 \times 10^{-4}$ sq in. total area, and a 3 hole of $2.26 \times 10^{-4}$ sq in. total area. The 7 mm barrel and plunger was used for these experiments and the results are shown in Figure 8. For both diesel fuel and diesel with BCM, 5 hole nozzle performance was better at the low speeds, whereas, 3 hole nozzle performance significantly improved at the higher speeds. In both cases, this can be explained by an improvement in spray distribution for the 3 hole nozzle as engine speed and air movement in the cylinder increased. The 5 hole nozzle performance was probably poorer as a result of under-penetration and failure to mix well with the air in the outer perimeter of the chamber. The difference at the 2400 rpm speed with BCM emphasizes again the importance of good atomization and mixing with air regardless of the presence of inhibitor.

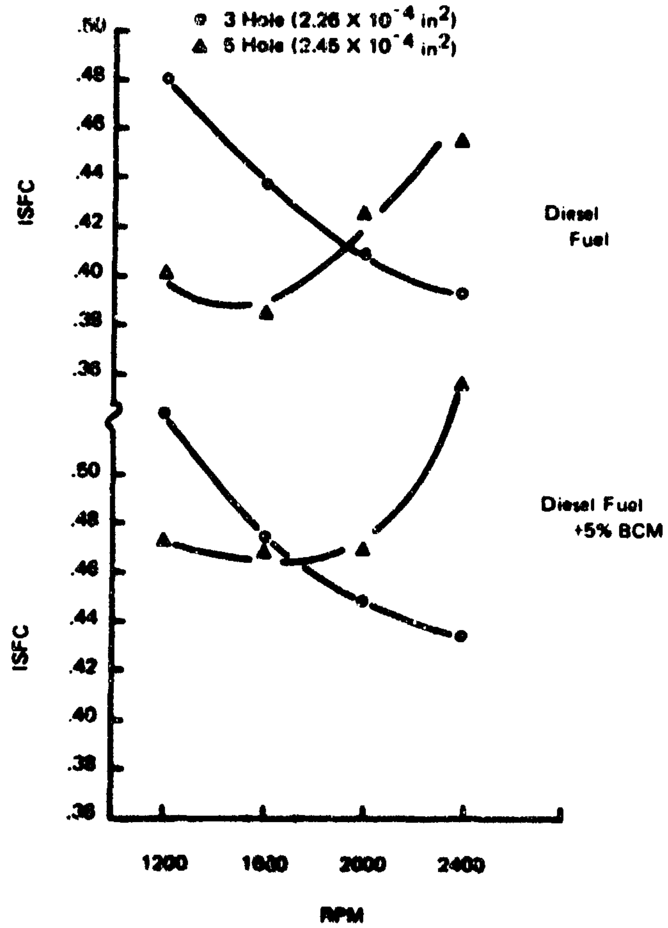



FIGURE 8. EFFECT OF NUMBER OF HOLES (7mm B&P)

The second experiment in this series compares the 4 hole nozzle performance ($3.02 \times 10^{-4}$ sq in.) to 6 hole nozzle ($2.94 \times 10^{-4}$ sq in.).

These data were obtained using the 10 mm barrel and plunger and are illustrated in Figure 9. As with the 3 and 5 hole nozzles, the directional effects of the 4 and 6 hole are the same with diesel fuel and the BCM-containing fuel. However, the relative differences are much greater with the BCM. The difference in number of holes with the diesel fuel would have the effect of under-penetration with the 6 hole nozzle as the speed increases, resulting in a relatively rich zone toward the center of the chamber and a lean zone toward the walls. As a result, combustion efficiency suffers. It was interesting to note the same general response of diesel + BCM to the change in injection system as observed with diesel fuel.

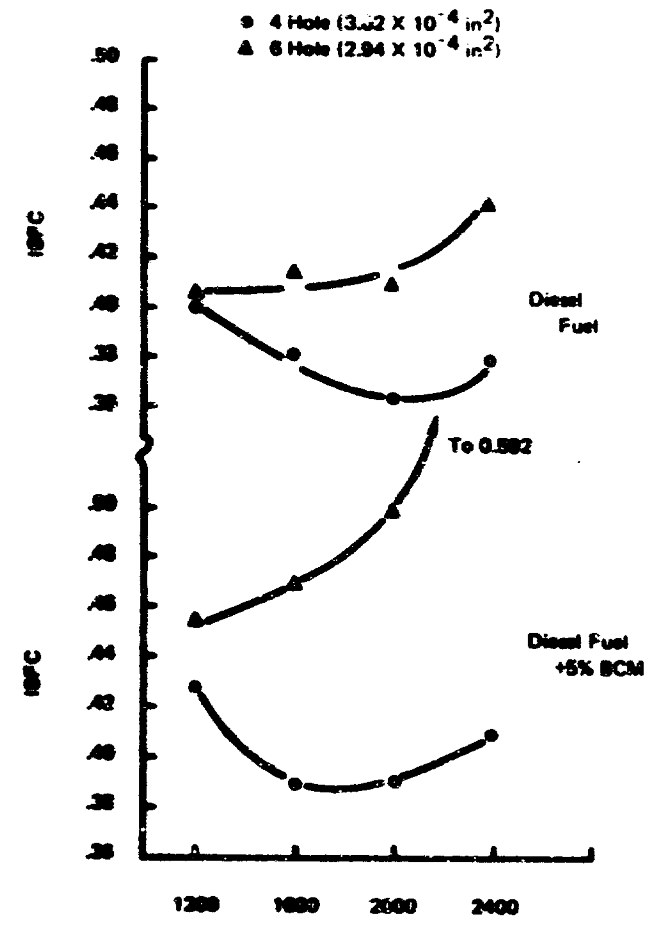



FIGURE 9. EFFECT OF NUMBER OF HOLES
(10mm B&P)

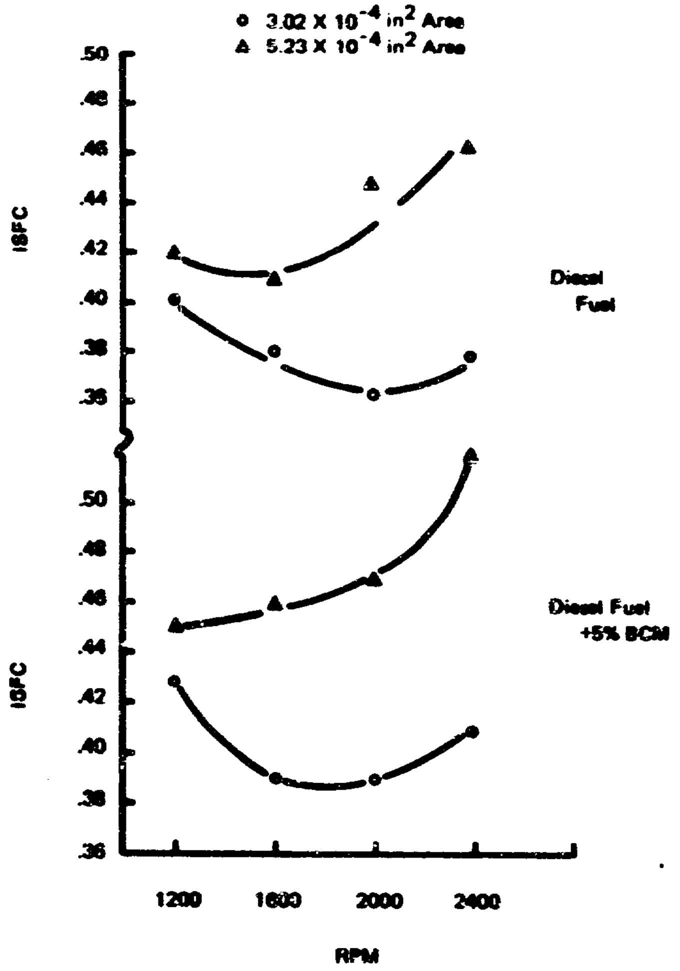



FIGURE 10. EFFECT OF TOTAL NOZZLE AREA
(4-Hole Nozzle 10mm B&P)

- *Effect of Nozzle Area (Number of Holes Equal)*

The final comparison of the effect of nozzle configuration was made with two nozzles having 4 holes, one with $3.02 \times 10^{-4}$ sq in. total area and the other $5.23 \times 10^{-4}$ sq in. total area. The 10 mm barrel and plunger were utilized for these comparisons as shown in Figure 10. Since the small 4 hole nozzle had the best performance for BCM and diesel fuel, the increase in total area resulted in the degradation of performance for both fuels. However, again the degradation was more marked for BCM than diesel fuel. In this case, the difference was expected since the poor performance was probably due to over-penetration and poor atomization.

### (6) Part Load Analysis

To verify that the relative performance of diesel fuel containing bromochloromethane was basically the same throughout the engine load range, a series of experiments was run at 2000 rpm (best power timing) utilizing the 10 mm barrel and plunger and 4 hole nozzle. These data, illustrated in Figure 11, were obtained with diesel fuel, diesel fuel plus 5 percent BCM and diesel fuel plus 10 percent BCM. With each fuel, the engine was set up at the indicated horsepower level established during the baseline runs, then the fuel flow rate systematically decreased until the misfire limit was reached. Since the engine was run at constant speed, the airflow rate was essentially constant, thus resulting in a decreasing fuel-air ratio as the fuel flow rate dropped. However, as may be observed by the three curves, the relative effect of the BCM in the fuels remained essentially unchanged throughout the load range. Therefore, it was concluded that diesel fuel with BCM responds basically the same regardless of engine load.

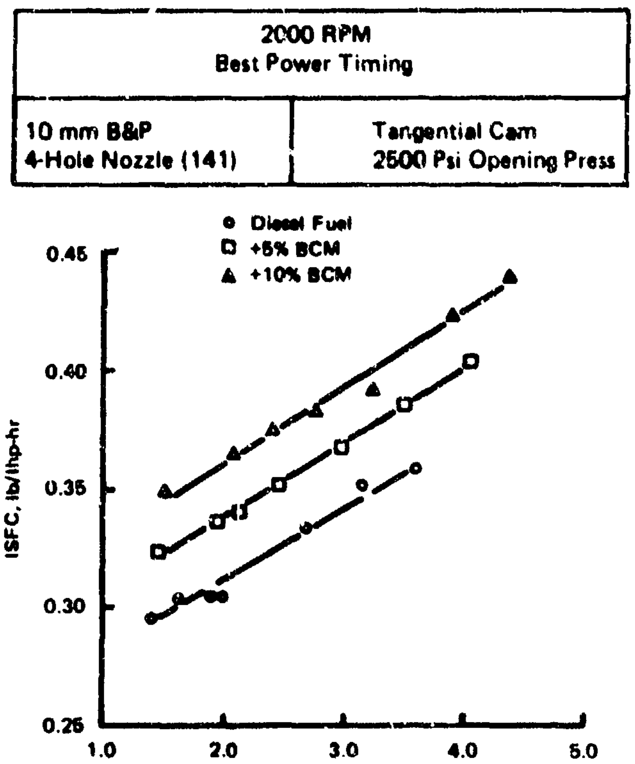



FIGURE 11. EFFECT OF FUEL FLOW RATE (ENGINE LOAD) ON PERFORMANCE

## V. DISCUSSION

From the results of these tests, the following observations are apparent:

- The response of diesel fuel with 5 percent BCM is in almost all cases directionally the same as diesel fuel with regard to injection system parameters. The treated fuel very often showed a greater sensitivity as far as response was concerned, however, it was demonstrated that satisfactory performance (ISFC within 9.5 percent of diesel fuel performance) could be obtained with the BCM containing fuel. Therefore, the primary objective of the project was met.

- The data obtained provide no clear-cut evidence of the mechanism of BCM flame inhibition in diesel engine operation. If the inhibiting mechanism could have been described, greater flexibility would be provided to the person ultimately responsible for achieving satisfactory performance in real engines in the field. Additionally, some insight could also be provided in describing the manner in which BCM inhibits combustion under ambient pressure and temperature conditions and provide improved vulnerability. There are two mechanisms generally proposed for flame inhibition. The first is a chemical inhibition in which the added material, or some of its reacted species, interferes with the free radical formation process necessary for hydrocarbon fuel ignition and combustion. The second mechanism suggested is a function of the physical properties of the fuel additive. Those additives having a high specific heat produce a heat sink effect precluding the attainment of stable flame temperatures. A possible contributor to both mechanisms is the high volatility of the bromochloromethane relative to diesel fuel in a low temperature environment (under 400°F). The quantity of BCM in the vapor state over the liquid will be significantly greater (as much as several hundred to 1 ratios) than the 5 vol percent added into the base fuel. Therefore, under some conditions, an additional contributing mechanism would be the overpowering presence of an inert material resulting in air-fuel ratios too lean for combustion. This factor is probably not too important in open chamber diesel engine combustion, but could be of significant importance in pre-chamber and MAN systems.

Until recently, it was generally considered that the halogenated materials functioned by a chemical inhibiting process. However, a presentation* was made by Eric R. Larsen (at an ACS meeting) which very strongly supports the heat sink mechanism theory. Unfortunately, the conclusions related in this presentation were based on the results presented in other publications (they conducted no experiments themselves), so there is reason to question the validity of their conclusions. Also, most prior publications and many workers in the field generally subscribe to the chemical inhibition mechanism even though there is no supporting data.

This comparison is illustrated in Figure 12 with diesel fuel results shown at the top and BCM at the bottom. The injection system configuration for each data point is indentified on the curve. As previously noted, the best performance for both BCM and diesel fuel was obtained with the 4 hole nozzle, although BCM performance was best across the board with the 10 mm barrel and plunger, whereas the diesel fuel responded best with the 10 mmm system at low speeds and the 7 mm barrel and plunger at the higher speeds. The worst performance comparison is not so direct. First, it is interesting to note that the degradation of performance with the BCM was significantly greater than the worst cases for diesel fuel. Secondly, the low-speed results were approximately the same. That is, the performance with the 3 hole nozzle and 7 mm barrel and plunger was worse in

*Halogenated Fire Extinguishants: A Physical Mechanism of Flame Suppression, Eric R. Larsen, Dow Chemical Co. Presented at the 166th National ACS Meeting, Aug 26-31, 1973, Paper No. 1NOE054.

both cases. Although at 1600 rpm, the 6 hole and 5 hole nozzle performance was almost as bad with BCM. The degradation of performance at high speed, however, shows a different effect. With diesel fuel, worst performance was obtained with the large area 4 hole nozzle and 10 mm barrel and plunger which resulted in very poor mixing and over-penetration. However, the worst performance with the BCM was with the 5 and 6 hole nozzle which would tend to result in under-penetration of the spray, thus concentrating the fuel in the mid-part of the chamber.

Injection and combustion data for the conditions in Figure 12 were compared to investigate the combustion event during the first part of the burning cycle. Diesel fuel performance is illustrated in Figures 13 and 14, and diesel fuel plus BCM in Figures 15 and 16. Injection performance is described in terms of start of injection and injection duration, and the combustion parameters are ignition delay, maximum rate of pressure rise and the occurrence of max pressure. Combustion data with the 6 and 4 hole nozzles and photographs were not obtained; therefore,

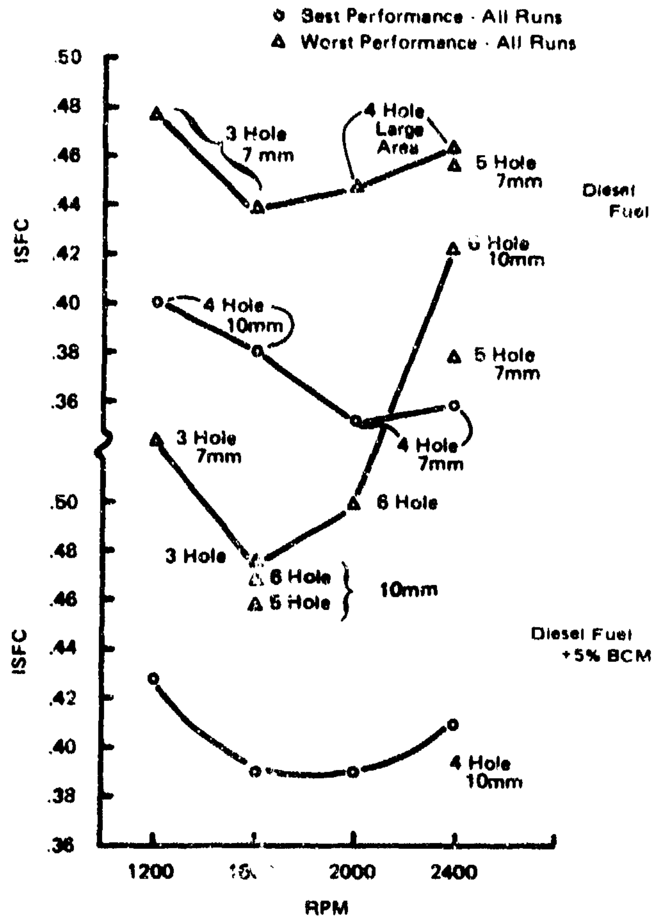



FIGURE 12. COMPARISON OF BEST AND WORST PERFORMANCE

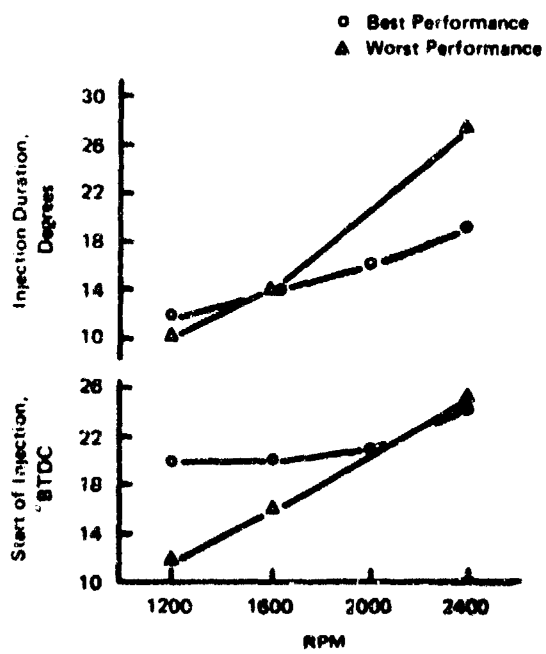



FIGURE 13. DIESEL FUEL

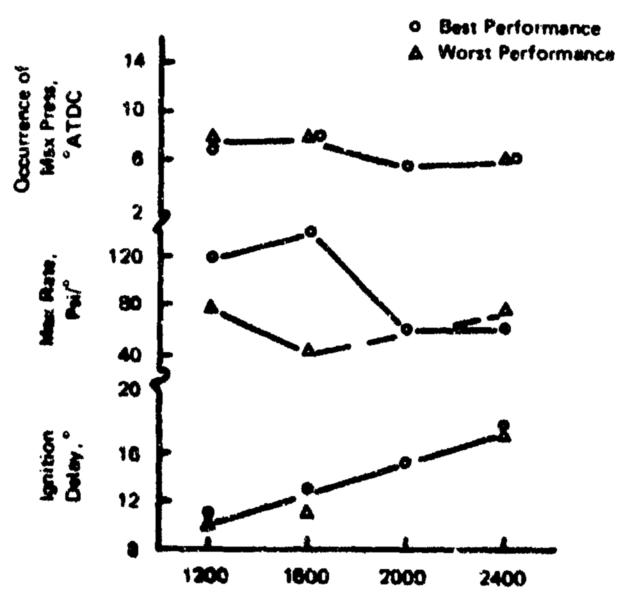



FIGURE 14. DIESEL FUEL

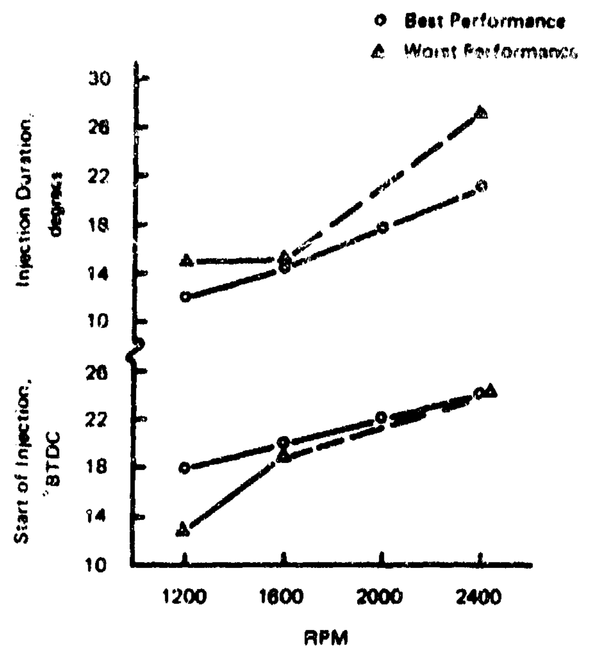


FIGURE 15. DIESEL FUEL WITH BCM

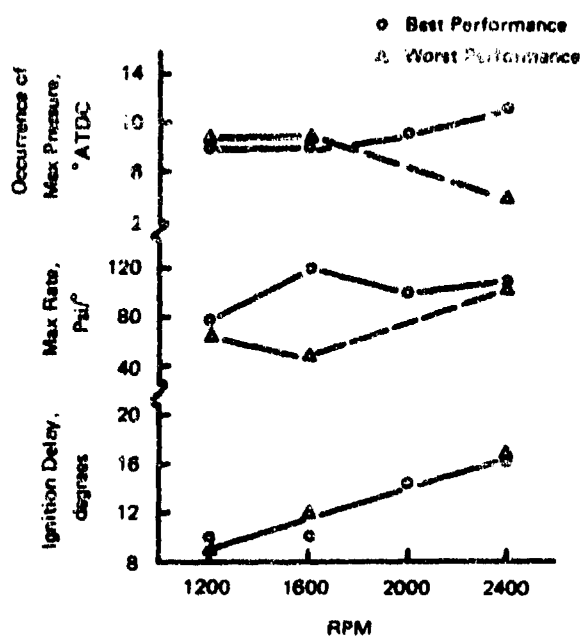


FIGURE 16. DIESEL FUEL WITH BCM

the comparison at 2400 is with the 5 hole 7 mm system which resulted in almost as poor a performance as the 4 and 6 hole nozzles for diesel fuel and diesel fuel with BCM, respectively.

When comparing the best and worst performances with BCM in terms of injection characteristics, results principally showed that at the higher speed, poorer performance was accompanied by longer duration; however, this was also the case with diesel fuel. The combustion data demonstrated no significant difference in ignition delay for the best and worst conditions, and when compared to diesel fuel, showed that there was no significant effect due to the presence of BCM. The best performance with BCM generally had a higher rate of pressure rise, and at the higher speeds, the occurrence of max pressure was later in the cycle. Again, these two trends were generally noted to be the same with diesel fuel.

The comparison of the injection and combustion results showed that the neat diesel fuel and diesel fuel plus BCM responded basically the same to changes in injection parameters. The part load analysis provided the same results. In addition to the same relative difference in ISFC throughout the load range, the lean flameout limit (the point where misfire occurred) was essentially the same in terms of diesel fuel flow rate, thus indicating no chemical interference in the lean region. Since the response was basically the same with and without BCM and there was no affect on ignition delay, it was concluded that there were no inhibiting effects during the combustion event from start of injection to occurrence of maximum combustion pressure. The absence of inhibition of the ignition delay process strongly suggested there was no chemical inhibition since free radical formation is essential to compression ignition. However, there remained the possibility that chemical inhibition might be a function of the presence of reacted halogenated species requiring temperatures above that found during the pre-flame period leading to the ignition and rapid combustion of the initial charge of fuel. Therefore, in order to evaluate combustion inhibition during the later part of the combustion event, a rate of heat release analysis was conducted. This analysis utilizes a computer program which calculates the heat release required to create the pressure

difference between the firing and motored trace. Input data for the analysis is derived from pressures and crank angles read from the pressure time diagrams. Tabulated data for the analysis and the results are in Appendix II.

For the purposes of the analysis, plots were made of several of the comparisons previously discussed. Figure 17 illustrates the rate of heat release for diesel fuel and treated fuel

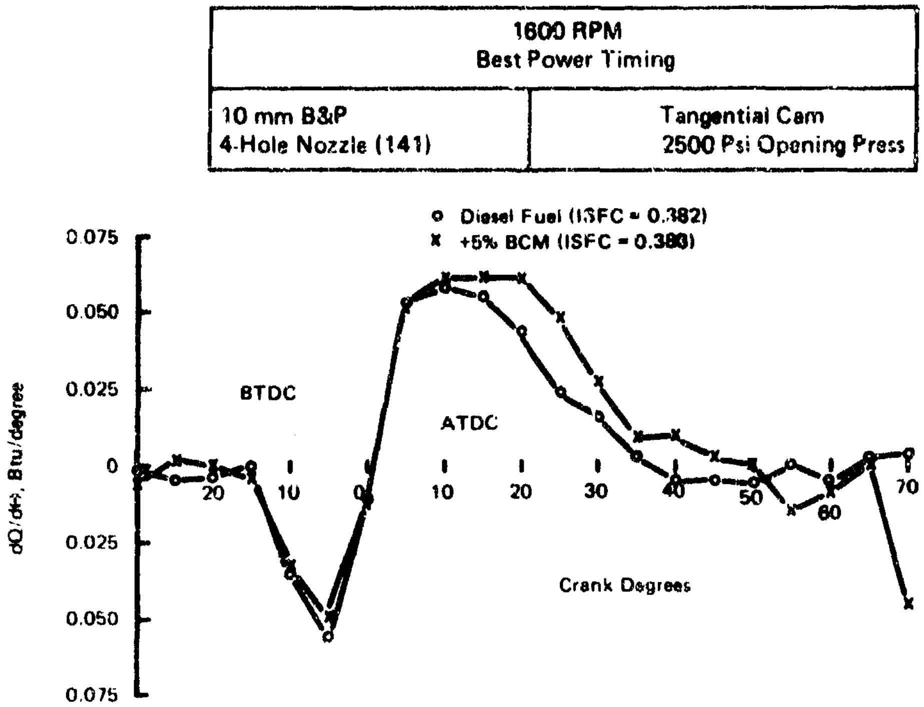



FIGURE 17. COMPARATIVE HEAT RELEASE VS CRANK ANGLE

when run under the best conditions and are compared at 1600 rpm. Absolute numbers of $dQ/d\theta$ data are not as important as the relative occurence of heat release events. Of principal interest is the shape of the curves which illustrate that the heat release period is essentially the same for both diesel fuel and the fuel treated with BCM.

Another comparsion between diesel fuel and the treated fuel is made in Figure 18. In this evaluation, the ISFC of diesel fuel was substantially better than that with BCM. However, again the heat release rate curves essentially follow each other in terms of the time in the cycle at which significant heat release took place. Other curves demonstrated the same type of performance thus leading to the conclusion that the presence of BCM does not inhibit the combustion process during the pressure build-up and expansion event as might have been anticipated had there been a chemical inhibiting mechanism involved. Therefore, as a result of these analyses, the conclusions of Larsen regarding the inhibiting mechanism of the halogen materials is strongly supported primarily because it is principally a physical effect rather than chemical, and the effects of blending BCM into diesel fuel causes performance variation in engines as a result of significant changes in heat content, density, and viscosity.

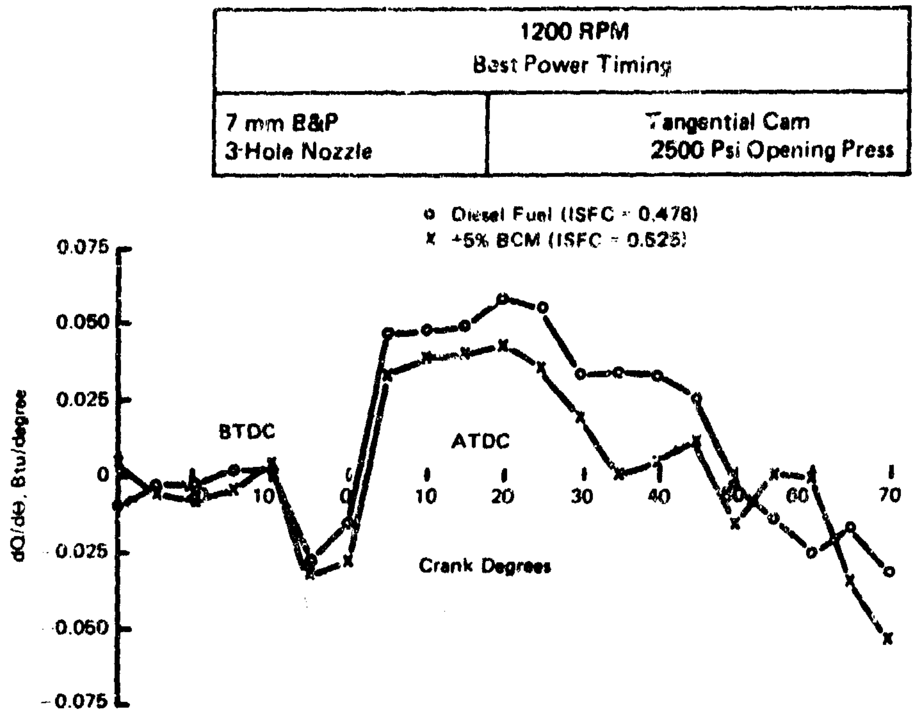



FIGURE 18. COMPARATIVE HEAT RELEASE VS CRANK ANGLE

# APPENDIX I. ENGINE PERFORMANCE AND COMBUSTION DATA

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel

**CAMSHAFT:** Tangential

**NOZZLE:** 4 Hole
0.0098" Dia
$3.02 \times 10^{-4}$ $in^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.0 | 10.2 | 12.5 |
| ISFC, lb/Ihp-hr | 0.402 | 0.381 | 0.363 | 0.379 |
| Start of injection, °BTDC | 20.0 | 20.0 | 22.5 | 24.5 |
| End of injection, °BTDC | 8.0 | 6.0 | 6.0 | 4.0 |
| Occur. of Rapid Rise, °BTDC | 8.5 | 6.5 | 7.0 | 6.5 |
| Occur. of Max Press., °ATDC | 7.0 | 8.0 | 8.0 | 9.0 |
| Max Comb. Press., psig | 800 | 700 | 640 | 540 |
| Ignition Delay, ° | 11.5 | 13.0 | 15.5 | 18.0 |
| Avg Rate, psi/° | 30.0 | 30.0 | 25.0 | 22.0 |
| Max Rate, psi/° | 120 | 140 | 173 | 167 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel

**CAMSHAFT:** Tangential

**NOZZLE:** 4 Hole
0.0098" Dia
$3.02 \times 10^{-4}$ $in^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.0 | 10.2 | 12.5 |
| ISFC, lb/Ihp-hr | 0.402 | 0.386 | 0.370 | 0.384 |
| Start of Injection, °BTDC | 20 | 20 | 23 | 25 |
| End of Injection, °BTDC | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Comments: Duplicate Performance Data

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel + 5% BCM

**CAMSHAFT:** Tangential

**NOZZLE:** 4 Hole
0.0098" Dia
$3.02 \times 10^{-4}$ in$^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.1 | 10.2 | 12.5 |
| ISFC, lb/ihp-hr | 0.428 | 0.388 | 0.388 | 0.407 |
| Start of Injection, °BTDC | 18.0 | 20.0 | 22.0 | 23.5 |
| End of Injection, °BTDC | 5.5 | 5.5 | 4.5 | 2.5 |
| Occur. of Rapid Rise, °BTDC | 8.0 | 8.0 | 7.5 | 7.5 |
| Occur. of Max Press., °ATDC | 8.0 | 7.5 | 9.0 | 11.5 |
| Max Comb. Press., psig | 740 | 700 | 600 | 520 |
| Ignition Delay, ° | 10.0 | 10.0 | 14.5 | 16.0 |
| Avg Rate, psi/° | 26 | 26 | 22 | 17 |
| Max Rate, psi/° | 76 | 124 | 106 | 115 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel + 5% BCM

**CAMSHAFT:** Tangential

**NOZZLE:** 4 Hole
0.0098" Dia
$3.02 \times 10^{-4}$ $in^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.1 | 10.2 | 12.5 |
| ISFC, lb/ihp-hr | 0.417 | 0.396 | 0.391 | 0.406 |
| Start of Injection, °BTDC | 18 | 20 | 22 | 24 |
| End of Injection, ° | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Comments: Duplicate Performance Data

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel

**CAMSHAFT:** Tangential

**NOZZLE:** 4 Hole
0.0098" Dia
$3.02 \times 10^{-4}$ $in^2$ Area

**PLUNGER DIA:** 7mm

Nozzle Opening Press: 2500 psi

| | | | | |
|---|---|---|---|---|
| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
| Indicated Horsepower | 5.9 | 8.2 | 10.6 | 12.6 |
| ISFC, lb/Ihp-hr | 0.459 | 0.418 | 0.352 | 0.358 |
| Start of Injection, °BTDC | 12.0 | 16.0 | 21.0 | 24.0 |
| End of Injection, ° | 0.5° ATC | 1.5° BTC | 4.5° BTC | 5.0° BTC |
| Occur. of Rapid Rise, °BTDC | 1.0 | 4.5 | 5.5 | 5.5 |
| Occur. of Max Press., °ATDC | 11.0 | 8.0 | 6.0 | 6.0 |
| Max Comb. Press., psig | 460 | 400 | 340 | 320 |
| Ignition Delay, ° | 11.0 | 11.5 | 15.5 | 18.5 |
| Avg Rate, psi/° | 15 | 14 | 17 | 14 |
| Max Rate, psi/° | 60 | 43 | 62 | 62 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 4 Hole
0.0098" Dia
$3.02 \times 10^{-4}$ $in^2$ Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 6.0 | 8.2 | 10.6 | 12.6 |
| ISFC, lb/Ihp-hr | 0.473 | 0.450 | 0.424 | 0.444 |
| Start of Injection, °BTDC | 14.0 | 18.0 | 22.0 | 24.5 |
| End of Injection, °BTDC | 3.5 | 2.5 | 4.5 | 4.0 |
| Occur. of Rapid Rise, °BTDC | 5.5 | 6.5 | 7.5 | 7.5 |
| Occur. of Max Press., °ATDC | 8.0 | 7.5 | 6.0 | 5.0 |
| Max Comb. Press., psig | 480 | 400 | 380 | 320 |
| Ignition Delay, ° | 8.5 | 11.5 | 14.5 | 17.0 |
| Avg Rate, psi/° | 16 | 14 | 16 | 14 |
| Max Rate, psi/° | 78 | 51 | 64 | 54 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 3 Hole
0.0098" Dia
$2.26 \times 10^{-4}$ $in^2$ Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.0 | 10.5 | 12.7 |
| ISFC, lb/Ihp-hr | 0.483 | 0.439 | 0.410 | 0.394 |
| Start of Injection, °BTDC | 12.0 | 16.0 | 21.0 | 24.0 |
| End of Injection, °BTDC | 1.5 | 2.0 | 4.0 | 5.0 |
| Occur. of Rapid Rise, °BTDC | 2.0 | 4.5 | 5.5 | 6.0 |
| Occur. of Max Press., °ATDC | 8.0 | 7.5 | 5.5 | 5.5 |
| Max Comb. Press., psig | 480 | 420 | 410 | 360 |
| Ignition Delay, ° | 10.0 | 11.5 | 15.5 | 18.0 |
| Avg Rate, psi/° | 20 | 17 | 19 | 19 |
| Max Rate, psi/° | 77 | 45 | 94 | 104 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel + 5% BCM

**CAMSHAFT:** Tangential

**NOZZLE:** 3 Hole
0.0098" Dia
$2.26 \times 10^{-4}$ $in^2$ Area

**PLUNGER DIA:** 7mm

Nozzle Opening Press: 2500 psi

| | | | | |
|---|---|---|---|---|
| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
| Indicated Horsepower | 5.7 | 8.0 | 10.3 | 12.7 |
| ISFC, lb/Ihp-hr | 0.526 | 0.474 | 0.448 | 0.433 |
| Start of Injection, °BTDC | 13.0 | 19.0 | 23.0 | 25.0 |
| End of Injection, °BTDC | 2.0 | 3.5 | 5.0 | 4.5 |
| Occur. of Rapid Rise, °BTDC | 4.0 | 7.0 | 7.0 | 7.0 |
| Occur. of Max Press., °ATDC | 7.0 | 7.0 | 5.0 | 3.5 |
| Max Comb. Press., psig | 480 | 420 | 400 | 320 |
| Ignition Delay, ° | 9.0 | 12.0 | 16.0 | 18.0 |
| Avg Rate, psi/° | 18 | 16 | 20 | 19 |
| Max Rate, psi/° | 68 | 47 | 88 | 85 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 5 Hole
0.0079" Dia
$2.45 \times 10^{-4}$ in$^2$ Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000* | 2400* |
|---|---|---|---|---|
| Indicated Horsepower | 5.9 | 8.1 | 10.4 | 12.5 |
| ISFC, lb/ihp-hr | 0.403 | 0.386 | 0.428 | 0.457 |
| Start of Injection, °BTDC | 17.0 | 18.0 | 21.0 | 24.0 |
| End of Injection, °ATDC | 2.5 | 4.5 | 3.0 | 2.5 |
| Occur. of Rapid Rise, °BTDC | 6.5 | 5.5 | 6.5 | 6.5 |
| Occur. of Max Press., °ATDC | 10.0 | 10.0 | 6.5 | 6.0 |
| Max Comb. Press., psig | 620 | 530 | 420 | 340 |
| Ignition Delay, ° | 10.5 | 12.5 | 14.5 | 17.5 |
| Avg Rate, psi/° | 18 | 16 | 17 | 12 |
| Max Rate, psi/° | 41 | 42 | 80 | 71 |

Comments: *Run at ~ 4000 psi opening pressure to eliminate post injcction.

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 5 Hole
0.0079" Dia
$2.45 \times 10^{-4}$ $in^2$ Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000* | 2400* |
|---|---|---|---|---|
| Indicated Horsepower | 5.9 | 8.1 | 10.4 | 12.6 |
| ISFC, lb/ihp-hr | 0.473 | 0.469 | 0.469 | 0.536 |
| Start of Injection, °BTDC | 16.0 | 18.0 | 21.0 | 25.0 |
| End of Injection, °ATDC | 5.0 | 6.5 | 3.0 | 2.5 |
| Occur. of Rapid Rise, °BTDC | 7.0 | 7.0 | 8.0 | 8.5 |
| Occur. of Max Press., °ATDC | 10.0 | 10.0 | 9.0 | 6.0 |
| Max Comb. Press., psig | 600 | 500 | 440 | 340 |
| Ignition Delay, ° | 9.0 | 11.0 | 13.0 | 16.5 |
| Avg Rate, psi/° | 18 | 14 | 14 | 14 |
| Max Rate, psi/° | 65 | 58 | 100 | 112 |

Comments: *Run at ~ 4000 psi opening pressure to eliminate post injection.

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel

**CAMSHAFT:** Tangential

**NOZZLE:** 5 Hole
0.0079" Dia
$2.45 \times 10^{-4}$ $in^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| | | | | |
|---|---|---|---|---|
| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
| Indicated Horsepower | 5.8 | 8.1 | 10.5 | 12.9 |
| ISFC, lb/Ihp-hr | 0.416 | 0.388 | 0.445 | 0.433 |
| Start of Injection, °BTDC | 12.0 | 17.0 | 17.0 | 18.0 |
| End of Injection, °ATDC | 3.5 | 0 | 3.0 | 7.0 |
| Occur. of Rapid Rise, °BTDC | 3.0 | 5.5 | 4.5 | 3.5 |
| Occur. of Max Press., °ATDC | 9.5 | 10.0 | 11.5 | 13.0 |
| Max Comb. Press., psig | 640 | 600 | 520 | 420 |
| Ignition Delay, ° | 9.0 | 11.5 | 12.5 | 14.5 |
| Avg Rate, psi/° | 22 | 21 | 18 | 13 |
| Max Rate, psi/° | 83 | 100 | 75 | 73 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 5 Hole
0.0079" Dia
$2.45 \times 10^{-4}$ $in^2$ Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

| | | | | |
|---|---|---|---|---|
| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
| Indicated Horsepower | 5.8 | 8.1 | 10.5 | 12.9 |
| ISFC, lb/Ihp-hr | 0.417 | 0.415 | 0.445 | 0.422 |
| Start of Injection, °BTDC | 12.0 | 17.0 | 17.0 | 18.0 |
| End of Injection, ° | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Comments: Duplicate Performance Data

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel + 5% BCM

**CAMSHAFT:** Tangential

**NOZZLE:** 5 Hole
0.0079" Dia
$2.45 \times 10^{-4}$ in$^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.1 | 10.5 | 12.9 |
| ISFC, lb/ihp-hr | 0.436 | 0.419 | 0.419 | 0.495 |
| Start of Injection, °BTDC | 13.0 | 14.0 | 15.5 | 21.0 |
| End of Injection, °ATDC | 3.5 | 5.5 | 5.5 | 2.5 |
| Occur. of Rapid Rise, °BTDC | 5.0 | 4.5 | 5.0 | 7.0 |
| Occur. of Max Press., °ATDC | 9.0 | 11.0 | 10.5 | 12.0 |
| Max Comb. Press., psig | 640 | 520 | 460 | 440 |
| Ignition Delay, ° | 8.0 | 9.5 | 10.5 | 14.0 |
| Avg Rate, psi/° | 21 | 17 | 14 | 15 |
| Max Rate, psi/° | 46 | 40 | 48 | 85 |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel + 5% BCM

**CAMSHAFT:** Tangential

**NOZZLE:** 5 Hole
0.0079" Dia
$2.45 \times 10^{-4}$ in$^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| | | | | |
|---|---|---|---|---|
| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
| Indicated Horsepower | 6.0 | 8.0 | 10.5 | 12.9 |
| ISFC, lb/Ihp-hr | 0.418 | 0.408 | 0.452 | 0.592 |
| Start of Injection, °BTDC | 13.0 | 14.0 | 16.0 | 21.0 |
| End of Injection, ° | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Comments: Duplicate Performance Data

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 6 Hole
0.0079" Dia
$2.94 \times 10^{-4}$ $in^2$ Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.0 | 10.2 | 12.5 |
| ISFC, lb/Ihp-hr | 0.407 | 0.416 | 0.410 | 0.442 |
| Start of Injection, °BTDC | 12.0 | 18.0 | 22.0 | 23.0 |
| End of Injection, ° | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

**FUEL:** Diesel + 5% BCM

**CAMSHAFT:** Tangential

**NOZZLE:** 6 Hole
0.0079" Dia
$2.94 \times 10^{-4}$ $in^2$ Area

**PLUNGER DIA:** 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.0 | 10.2 | 12.5 |
| ISFC, lb/Ihp-hr | 0.455 | 0.468 | 0.499 | 0.592 |
| Start of Injection, °BTDC | 12.0 | 20.0 | 19.0 | 21.0 |
| End of Injection, ° | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Commer

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 4 Hole
0.0129" Dia
$5.23 \times 10^{-4}$ $in^2$ Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 6.0 | 8.1 | 10.7 | 12.6 |
| ISFC, lb/Ihp-hr | 0.422 | 0.410 | 0.449 | 0.463 |
| Start of Injection, °BTDC | 14.0 | 20.0 | 27.0 | 28.0 |
| End of Injection, ° | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Comments:

## ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 4 Hole
0.0129" Dia
$5.23 \times 10^{-4}$ $in^2$ Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

| Engine Speed, rpm | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|
| Indicated Horsepower | 5.8 | 8.0 | 10.5 | 12.9 |
| ISFC, lb/Ihp-hr | 0.450 | 0.459 | 0.469 | 0.519 |
| Start of Injection, °BTDC | 15.0 | 17.0 | 22.0 | 23.0 |
| End of Injection, ° | | | | |
| Occur. of Rapid Rise, °BTDC | | | | |
| Occur. of Max Press., °ATDC | | | | |
| Max Comb. Press., psig | | | | |
| Ignition Delay, ° | | | | |
| Avg Rate, psi/° | | | | |
| Max Rate, psi/° | | | | |

Comments:

# APPENDIX II. HEAT RELEASE ANALYSIS DATA

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 1200 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 15.000 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 174.00 | 30.00 | -.008982 |
| 236.20 | 25.00 | -.001517 |
| 298.30 | 20.00 | -.002704 |
| 397.70 | 15.00 | .001664 |
| 459.90 | 10.00 | .002435 |
| 534.50 | 5.00 | -.026777 |
| 820.40 | 0.00 | -.015385 |
| 969.50 | 5.00 | .046683 |
| 1006.80 | 10.00 | .048470 |
| 957.10 | 15.00 | .049000 |
| 870.10 | 20.00 | .058544 |
| 808.00 | 25.00 | .057290 |
| 683.60 | 30.00 | .033576 |
| 596.60 | 35.00 | .034674 |
| 509.60 | 40.00 | .034442 |
| 459.90 | 45.00 | .027243 |
| 385.30 | 50.00 | -.001042 |
| 335.60 | 55.00 | -.013119 |
| 273.50 | 60.00 | -.024978 |
| 236.20 | 65.00 | -.016454 |
| 198.90 | 70.00 | -.031941 |

W = 3.6580E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 1200 RPM, 8CM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.000 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P<br>( P S I ) | THETA<br>( D E G ) | DQ/DTHETA |
|---|---|---|
| 157.40 | 30.00 | .005967 |
| 181.60 | 25.00 | -.005531 |
| 278.50 | 20.00 | -.007194 |
| 363.30 | 15.00 | -.002879 |
| 460.20 | 10.00 | .002857 |
| 496.50 | 5.00 | -.028593 |
| 835.60 | 0.00 | -.027474 |
| 932.50 | 5.00 | .033810 |
| 932.50 | 10.00 | .037802 |
| 884.00 | 15.00 | .042172 |
| 799.30 | 20.00 | .043567 |
| 714.50 | 25.00 | .037963 |
| 605.50 | 30.00 | .021162 |
| 508.60 | 35.00 | .001694 |
| 399.60 | 40.00 | .005073 |
| 363.30 | 45.00 | .012747 |
| 290.60 | 50.00 | -.015774 |
| 242.20 | 55.00 | .001594 |
| 218.00 | 60.00 | .000880 |
| 181.60 | 65.00 | -.032777 |
| 133.20 | 70.00 | -.055547 |

W = 2.9919E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 1600 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 15.400 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 172.60 | 30.00 | -.007124 |
| 230.10 | 25.00 | -.000358 |
| 287.60 | 20.00 | -.003005 |
| 388.30 | 15.00 | -.000373 |
| 460.20 | 10.00 | .001624 |
| 532.10 | 5.00 | -.029991 |
| 848.40 | 0.00 | -.020011 |
| 992.20 | 5.00 | .045038 |
| 1006.60 | 10.00 | .049287 |
| 977.80 | 15.00 | .057114 |
| 891.60 | 20.00 | .057738 |
| 805.30 | 25.00 | .068807 |
| 733.40 | 30.00 | .079315 |
| 661.50 | 35.00 | .076168 |
| 589.60 | 40.00 | .073418 |
| 532.10 | 45.00 | .037865 |
| 445.80 | 50.00 | .027456 |
| 417.00 | 55.00 | .075908 |
| 373.90 | 60.00 | -.011107 |
| 316.40 | 65.00 | -.050129 |
| 273.20 | 70.00 | -.051323 |

W = 4.2722E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 1600 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.200 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 153.30 | 30.00 | -.017296 |
| 230.00 | 25.00 | -.007540 |
| 306.60 | 20.00 | -.003315 |
| 398.60 | 15.00 | .002795 |
| 459.90 | 10.00 | -.027787 |
| 797.20 | 5.00 | -.048202 |
| 1011.80 | 0.00 | -.015648 |
| 1103.80 | 5.00 | .041416 |
| 1103.80 | 10.00 | .044363 |
| 1011.80 | 15.00 | .043714 |
| 904.50 | 20.00 | .048687 |
| 797.20 | 25.00 | .041947 |
| 674.50 | 30.00 | .037844 |
| 597.90 | 35.00 | .039258 |
| 505.90 | 40.00 | .023489 |
| 444.60 | 45.00 | -.000463 |
| 352.60 | 50.00 | -.007639 |
| 321.90 | 55.00 | .018027 |
| 275.90 | 60.00 | -.018630 |
| 230.00 | 65.00 | -.038188 |
| 184.00 | 70.00 | -.053822 |

W = 3.6098E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2000 RPM, DF-2 FUEL

| | | | |
|---|---|---|---|
| BORE DIAMETER | = | 3.800 | INCHES |
| CRANK RADIUS | = | 1.875 | INCHES |
| CONNECTING ROD LENGTH | = | 6.375 | INCHES |
| COMPRESSION RATIO | = | 16.700 | |
| VOLUMETRIC EFFICIENCY | = | .653 | |
| INLET PRESSURE | = | 13.830 | PSI |
| INLET TEMPERATURE | = | 560.000 | DEG. R |
| AIR/FUEL RATIO | = | 15.200 | |
| FUEL MOLECULAR WT | = | 184.000 | LB/LB-MOLE |
| SF1 | = | 0.000 | |
| SF2 | = | 1.000 | |
| PATM | = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 147.20 | 30.00 | -.008560 |
| 202.40 | 25.00 | -.008703 |
| 294.40 | 20.00 | -.006649 |
| 386.40 | 15.00 | .000423 |
| 460.00 | 10.00 | -.009484 |
| 625.60 | 5.00 | -.058096 |
| 1104.00 | 0.00 | -.062662 |
| 1122.40 | 5.00 | .026863 |
| 1085.60 | 10.00 | .040514 |
| 1012.00 | 15.00 | .047907 |
| 901.60 | 20.00 | .062910 |
| 846.40 | 25.00 | .093667 |
| 772.80 | 30.00 | .106674 |
| 717.60 | 35.00 | .140740 |
| 662.40 | 40.00 | .191394 |
| 625.60 | 45.00 | .297347 |
| 570.40 | 50.00 | .196388 |
| 496.80 | 55.00 | .239236 |
| 478.40 | 60.00 | -1.345501 |
| 432.20 | 65.00 | -.003438 |
| 386.40 | 70.00 | .498421 |

previous error

W = 5.0757E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2000 RPM, BCM FUEL

| | | | |
|---|---|---|---|
| BORE DIAMETER | = | 3.800 | INCHES |
| CRANK RADIUS | = | 1.875 | INCHES |
| CONNECTING ROD LENGTH | = | 6.375 | INCHES |
| COMPRESSION RATIO | = | 16.700 | |
| VOLUMETRIC EFFICIENCY | = | .653 | |
| INLET PRESSURE | = | 13.830 | PSI |
| INLET TEMPERATURE | = | 560.000 | DEG. R |
| AIR/FUEL RATIO | = | 14.200 | |
| FUEL MOLECULAR WT | = | 181.200 | LB/LB-MOLE |
| SF1 | = | 0.000 | |
| SF2 | = | 1.000 | |
| PATM | = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 146.40 | 30.00 | -.011896 |
| 209.10 | 25.00 | -.008007 |
| 292.70 | 20.00 | -.000843 |
| 355.50 | 15.00 | -.001511 |
| 460.00 | 10.00 | -.049753 |
| 941.00 | 5.00 | -.070880 |
| 1171.00 | 0.00 | -.020857 |
| 1254.60 | 5.00 | .045940 |
| 1233.70 | 10.00 | .054895 |
| 1150.00 | 15.00 | .071402 |
| 1066.40 | 20.00 | .084849 |
| 941.00 | 25.00 | .090366 |
| 857.30 | 30.00 | .128481 |
| 773.70 | 35.00 | .089559 |
| 648.20 | 40.00 | .022855 |
| 564.60 | 45.00 | .092047 |
| 522.80 | 50.00 | .072022 |
| 439.10 | 55.00 | -.065269 |
| 376.40 | 60.00 | -.023238 |
| 334.60 | 65.00 | -.016195 |
| 292.90 | 70.00 | -.054222 |

W = 4.8335E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2400 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 15.800 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 138.00 | 30.00 | -.015325 |
| 207.00 | 25.00 | -.002381 |
| 253.00 | 20.00 | -.002330 |
| 345.00 | 15.00 | -.007268 |
| 460.00 | 10.00 | -.040385 |
| 851.00 | 5.00 | -.071818 |
| 1196.00 | 0.00 | -.033005 |
| 1311.00 | 5.00 | .053740 |
| 1288.00 | 10.00 | .062487 |
| 1219.00 | 15.00 | .084113 |
| 1127.00 | 20.00 | .118405 |
| 1058.00 | 25.00 | .171254 |
| 966.00 | 30.00 | .206788 |
| 874.00 | 35.00 | .321638 |
| 805.00 | 40.00 | 1.373376 |
| 759.00 | 45.00 | -.583652 |
| 713.00 | 50.00 | -.160553 |
| 644.00 | 55.00 | -.078887 |
| 598.00 | 60.00 | -.022469 |
| 529.00 | 65.00 | .023640 |
| 483.00 | 70.00 | .012634 |

W = 6.3817E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2400 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6,375 | INCHES |
| COMPRESSION RATIO = | 16,700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13,790 | PSI |
| INLET TEMPERATURE = | 560,000 | DEG. R |
| AIR/FUEL RATIO = | 14,400 | |
| FUEL MOLECULAR WT = | 181,200 | LB/LB-MOLE |
| SF1 = | 0,000 | |
| SF2 = | 1,000 | |
| PATM = | 0,000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 81,20 | 30.00 | -,034159 |
| 189,40 | 25.00 | -,017398 |
| 270,60 | 20.00 | -,009067 |
| 378,80 | 15.00 | -,003184 |
| 460,00 | 10.00 | -,069646 |
| 1136,50 | 5.00 | -,078074 |
| 1190,60 | 0.00 | ,015542 |
| 1353,00 | 5.00 | ,064303 |
| 1325,90 | 10.00 | ,057915 |
| 1217,70 | 15.00 | ,076625 |
| 1136,50 | 20.00 | ,111377 |
| 1028,30 | 25.00 | ,122046 |
| 920,00 | 30.00 | ,155273 |
| 838,90 | 35.00 | ,232207 |
| 757,70 | 40.00 | ,243716 |
| 659,40 | 45.00 | ,198330 |
| 595,30 | 50.00 | ,723374 |
| 541,20 | 55.00 | -,080752 |
| 460,00 | 60.00 | -,470356 |
| 405,90 | 65.00 | -,268417 |
| 351,80 | 70.00 | -,283175 |

W = 5.5561E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 1200 RPM, DF-2 FUE

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.400 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 174.80 | 30.00 | .002334 |
| 211.50 | 25.00 | .000605 |
| 276.00 | 20.00 | -.000635 |
| 349.50 | 15.00 | -.003891 |
| 460.00 | 10.00 | -.002950 |
| 533.60 | 5.00 | -.025606 |
| 809.60 | 0.00 | -.014372 |
| 956.80 | 5.00 | .046807 |
| 1002.80 | 10.00 | .049890 |
| 956.80 | 15.00 | .050289 |
| 874.00 | 20.00 | .045623 |
| 754.40 | 25.00 | .030310 |
| 634.80 | 30.00 | .024040 |
| 542.80 | 35.00 | .017729 |
| 450.80 | 40.00 | -.001072 |
| 368.00 | 45.00 | -.009412 |
| 303.60 | 50.00 | -.006399 |
| 257.60 | 55.00 | -.009782 |
| 211.50 | 60.00 | -.003415 |
| 193.20 | 65.00 | .003927 |
| 165.60 | 70.00 | -.015147 |

W = 3.2070E+02

CLR DIESEL HEAT RELEASE DATA -- ADR 6961 TIP, 10 MM B+P, 1200 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 16.600 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 201.20 | 30.00 | .000074 |
| 249.10 | 25.00 | .001383 |
| 316.10 | 20.00 | .002878 |
| 383.20 | 15.00 | .003220 |
| 459.80 | 10.00 | -.002721 |
| 565.20 | 5.00 | -.028903 |
| 843.30 | 0.00 | -.014123 |
| 996.30 | 5.00 | .050981 |
| 1053.80 | 10.00 | .056999 |
| 1015.50 | 15.00 | .059831 |
| 938.80 | 20.00 | .058296 |
| 823.80 | 25.00 | .042139 |
| 699.30 | 30.00 | .020774 |
| 574.80 | 35.00 | .011041 |
| 488.60 | 40.00 | .013049 |
| 411.90 | 45.00 | .006993 |
| 353.30 | 50.00 | -.000148 |
| 297.00 | 55.00 | -.029250 |
| 229.90 | 60.00 | -.026626 |
| 201.20 | 65.00 | .012893 |
| 141.60 | 70.00 | .028153 |

W =    3.4893E+02

CLR DIESEL HEAT RELEASE DATA -- AOB 6961 TIP, 10 MM B+P, 1600 RPM, DF-2 FUE

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.200 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 149.20 | 30.00 | -.016661 |
| 223.70 | 25.00 | -.004945 |
| 285.90 | 20.00 | -.001714 |
| 372.90 | 15.00 | -.001397 |
| 459.90 | 10.00 | -.016171 |
| 671.20 | 5.00 | -.048328 |
| 1019.30 | 0.00 | -.026778 |
| 1156.00 | 5.00 | .066636 |
| 1267.80 | 10.00 | .093407 |
| 1243.00 | 15.00 | .095419 |
| 1143.60 | 20.00 | .099530 |
| 1031.70 | 25.00 | .104626 |
| 907.40 | 30.00 | .068046 |
| 758.20 | 35.00 | .024281 |
| 646.40 | 40.00 | .033171 |
| 559.40 | 45.00 | .011978 |
| 472.30 | 50.00 | -.026247 |
| 397.80 | 55.00 | .000412 |
| 360.50 | 60.00 | .010171 |
| 310.80 | 65.00 | -.001347 |
| 285.90 | 70.00 | .025743 |

W = 4.8221E+02

FUE

CLR DIESEL HEAT RELEASE DATA -- ADS 6961 TIP, 10 MM B+P, 1600 RPM, BCM FUEL

| | | | |
|---|---|---|---|
| BORE DIAMETER | = | 3.800 | INCHES |
| CRANK RADIUS | = | 1.875 | INCHES |
| CONNECTING ROD LENGTH | = | 6.375 | INCHES |
| COMPRESSION RATIO | = | 16.700 | |
| VOLUMETRIC EFFICIENCY | = | .572 | |
| INLET PRESSURE | = | 13.870 | PSI |
| INLET TEMPERATURE | = | 560.000 | DEG. R |
| AIR/FUEL RATIO | = | 15.900 | |
| FUEL MOLECULAR WT | = | 181.200 | LB/LB-MOLE |
| SF1 | = | 0.000 | |
| SF2 | = | 1.000 | |
| PATM | = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 181.70 | 30.00 | -.007589 |
| 242.20 | 25.00 | -.000441 |
| 302.80 | 20.00 | .003915 |
| 363.30 | 15.00 | .000266 |
| 460.20 | 10.00 | -.004137 |
| 557.10 | 5.00 | .008354 |
| 487.70 | 0.00 | .052758 |
| 956.70 | 5.00 | .096326 |
| 1053.60 | 10.00 | .069385 |
| 1041.50 | 15.00 | .074383 |
| 980.90 | 20.00 | .089129 |
| 920.40 | 25.00 | .101327 |
| 823.50 | 30.00 | .071141 |
| 702.40 | 35.00 | .039873 |
| 605.50 | 40.00 | .022112 |
| 508.60 | 45.00 | .025880 |
| 460.20 | 50.00 | .042696 |
| 399.70 | 55.00 | -.013196 |
| 339.10 | 60.00 | -.032059 |
| 290.60 | 65.00 | -.023337 |
| 254.30 | 70.00 | -.026668 |

W = 4.3495E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 2000 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.600 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .653 | |
| INLET PRESSURE = | 13.830 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.000 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 158.20 | 30.00 | -.008551 |
| 215.70 | 25.00 | -.007009 |
| 302.00 | 20.00 | -.004334 |
| 388.30 | 15.00 | .001523 |
| 460.20 | 10.00 | -.006759 |
| 604.00 | 5.00 | -.044134 |
| 977.80 | 0.00 | -.023667 |
| 1164.80 | 5.00 | .068658 |
| 1222.30 | 10.00 | .088186 |
| 1236.70 | 15.00 | .130180 |
| 1207.90 | 20.00 | .167722 |
| 1107.30 | 25.00 | .187935 |
| 1006.60 | 30.00 | .246631 |
| 891.60 | 35.00 | .171786 |
| 747.80 | 40.00 | -.068326 |
| 618.40 | 45.00 | -.018635 |
| 546.40 | 50.00 | .104102 |
| 488.90 | 55.00 | -.004014 |
| 417.00 | 60.00 | .005416 |
| 388.30 | 65.00 | -.063456 |
| 330.70 | 70.00 | -.220298 |

W = 5.4848E+02

FUEL

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 2000 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .653 | |
| INLET PRESSURE = | 13.830 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.900 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 186.50 | 30.00 | -.002329 |
| 236.20 | 25.00 | .003098 |
| 285.90 | 20.00 | .000195 |
| 372.90 | 15.00 | -.001451 |
| 459.90 | 10.00 | -.001916 |
| 546.90 | 5.00 | -.029884 |
| 845.20 | 0.00 | -.017522 |
| 994.40 | 5.00 | .049791 |
| 1031.70 | 10.00 | .058909 |
| 1019.30 | 15.00 | .072836 |
| 957.10 | 20.00 | .082314 |
| 882.50 | 25.00 | .081135 |
| 770.70 | 30.00 | .059528 |
| 671.20 | 35.00 | .062692 |
| 596.60 | 40.00 | .062961 |
| 522.10 | 45.00 | .028152 |
| 447.50 | 50.00 | -.000592 |
| 385.30 | 55.00 | -.005294 |
| 335.60 | 60.00 | -.000063 |
| 298.30 | 65.00 | -.006640 |
| 261.00 | 70.00 | -.032509 |

W = 4.2735E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 2400 RPM, DF-2 FUE

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.200 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATH = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 123.80 | 30.00 | -.017308 |
| 194.60 | 25.00 | -.008295 |
| 265.40 | 20.00 | -.004743 |
| 353.80 | 15.00 | -.005184 |
| 459.90 | 10.00 | -.006356 |
| 566.10 | 5.00 | -.037774 |
| 919.90 | 0.00 | -.025936 |
| 1061.40 | 5.00 | .064449 |
| 1185.20 | 10.00 | .102682 |
| 1238.30 | 15.00 | .133348 |
| 1185.20 | 20.00 | .172401 |
| 1149.80 | 25.00 | .260972 |
| 1026.00 | 30.00 | .282956 |
| 937.60 | 35.00 | .784994 |
| 831.40 | 40.00 | -1.906309 |
| 725.30 | 45.00 | .143599 |
| 601.50 | 50.00 | .244299 |
| 566.10 | 55.00 | -.362168 |
| 513.00 | 60.00 | .038196 |
| 442.20 | 65.00 | .325705 |
| 389.20 | 70.00 | .748122 |

W = 6.0332E+02

FUE

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 2400 RPM, BCM FUE

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 12.400 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 164.30 | 30.00 | -.004358 |
| 213.60 | 25.00 | -.001831 |
| 279.30 | 20.00 | -.002034 |
| 361.50 | 15.00 | -.002966 |
| 460.00 | 10.00 | -.031353 |
| 788.60 | 5.00 | -.045792 |
| 985.80 | 0.00 | -.002101 |
| 1166.50 | 5.00 | .064112 |
| 1199.40 | 10.00 | .077885 |
| 1199.40 | 15.00 | .111823 |
| 1150.10 | 20.00 | .161658 |
| 1117.20 | 25.00 | .278149 |
| 1051.50 | 30.00 | .481190 |
| 952.90 | 35.00 | 1.450249 |
| 821.50 | 40.00 | -3.755054 |
| 739.40 | 45.00 | -.209251 |
| 640.80 | 50.00 | -.063780 |
| 575.10 | 55.00 | .024916 |
| 492.90 | 60.00 | .159124 |
| 443.60 | 65.00 | .187643 |
| 377.90 | 70.00 | 26.639926 |

W = 6.0089E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1200 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 15.500 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 195.50 | 30.00 | .000339 |
| 241.50 | 25.00 | .000686 |
| 310.50 | 20.00 | -.001762 |
| 402.50 | 15.00 | .003552 |
| 460.00 | 10.00 | .003615 |
| 529.00 | 5.00 | -.007346 |
| 632.50 | 0.00 | .017809 |
| 908.50 | 5.00 | .059287 |
| 943.00 | 10.00 | .050735 |
| 943.00 | 15.00 | .060411 |
| 874.00 | 20.00 | .061856 |
| 805.00 | 25.00 | .061301 |
| 701.50 | 30.00 | .049103 |
| 621.00 | 35.00 | .054639 |
| 552.00 | 40.00 | .038773 |
| 471.50 | 45.00 | .029155 |
| 425.50 | 50.00 | .042759 |
| 379.50 | 55.00 | .020783 |
| 333.50 | 60.00 | .010276 |
| 299.00 | 65.00 | -.012653 |
| 253.00 | 70.00 | -.053763 |

W = 3.9715E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1200 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.800 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 174.00 | 30.00 | -.008983 |
| 236.20 | 25.00 | .000794 |
| 285.90 | 20.00 | .002181 |
| 360.50 | 15.00 | -.002018 |
| 459.90 | 10.00 | -.003228 |
| 546.90 | 5.00 | -.033173 |
| 882.50 | 0.00 | -.024487 |
| 1006.80 | 5.00 | .045212 |
| 1044.10 | 10.00 | .053340 |
| 1006.80 | 15.00 | .064670 |
| 957.10 | 20.00 | .076703 |
| 870.10 | 25.00 | .071255 |
| 770.70 | 30.00 | .060630 |
| 671.20 | 35.00 | .048823 |
| 584.20 | 40.00 | .050751 |
| 522.10 | 45.00 | .076648 |
| 484.80 | 50.00 | .067197 |
| 422.60 | 55.00 | -.009351 |
| 360.50 | 60.00 | -.009613 |
| 323.20 | 65.00 | .003963 |
| 285.90 | 70.00 | -.023579 |

W = 4.4119E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1600 RPM, DF-2 FUEL

| | | | |
|---|---|---|---|
| BORE DIAMETER = | 3.900 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 15.700 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 178.10 | 30.00 | -.000809 |
| 222.60 | 25.00 | -.001699 |
| 296.80 | 20.00 | -.000819 |
| 371.00 | 15.00 | -.000076 |
| 460.00 | 10.00 | -.002336 |
| 549.10 | 5.00 | -.034349 |
| 890.40 | 0.00 | -.026375 |
| 1009.10 | 5.00 | .040536 |
| 1009.10 | 10.00 | .051753 |
| 1009.10 | 15.00 | .072703 |
| 949.80 | 20.00 | .079037 |
| 875.60 | 25.00 | .085057 |
| 786.50 | 30.00 | .104547 |
| 742.00 | 35.00 | .128900 |
| 653.00 | 40.00 | .077681 |
| 578.80 | 45.00 | .060278 |
| 504.60 | 50.00 | .058227 |
| 460.00 | 55.00 | .090248 |
| 415.50 | 60.00 | .139674 |
| 400.70 | 65.00 | .097483 |
| 341.30 | 70.00 | -.217102 |

W = 4.8294E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1600 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.600 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 138.00 | 30.00 | -.025131 |
| 230.00 | 25.00 | -.004674 |
| 276.00 | 20.00 | -.000687 |
| 368.00 | 15.00 | -.002997 |
| 460.00 | 10.00 | -.015398 |
| 659.30 | 5.00 | -.023637 |
| 797.30 | 0.00 | .005207 |
| 981.30 | 5.00 | .052046 |
| 1012.00 | 10.00 | .057016 |
| 1012.00 | 15.00 | .069628 |
| 935.30 | 20.00 | .075151 |
| 874.00 | 25.00 | .095026 |
| 797.30 | 30.00 | .116099 |
| 751.30 | 35.00 | .105476 |
| 628.70 | 40.00 | .073237 |
| 598.00 | 45.00 | .235035 |
| 567.30 | 50.00 | .274360 |
| 506.00 | 55.00 | .139622 |
| 460.00 | 60.00 | .165962 |
| 414.00 | 65.00 | .164710 |
| 383.30 | 70.00 | .448744 |

W = 5.0140E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 2000 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .653 | |
| INLET PRESSURE = | 13.830 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.500 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 141.50 | 30.00 | -.015804 |
| 212.30 | 25.00 | -.006855 |
| 283.10 | 20.00 | -.003516 |
| 371.50 | 15.00 | -.001903 |
| 460.00 | 10.00 | -.004301 |
| 566.20 | 5.00 | -.050991 |
| 1043.80 | 0.00 | -.053207 |
| 1114.60 | 5.00 | .034272 |
| 1079.20 | 10.00 | .040574 |
| 1008.50 | 15.00 | .064045 |
| 973.10 | 20.00 | .083715 |
| 866.90 | 25.00 | .079716 |
| 796.20 | 30.00 | .129962 |
| 760.80 | 35.00 | .182498 |
| 690.00 | 40.00 | .212384 |
| 654.60 | 45.00 | .551507 |
| 619.20 | 50.00 | -2.686332 |
| 566.20 | 55.00 | -.262349 |
| 513.10 | 60.00 | .038999 |
| 442.30 | 65.00 | .146557 |
| 406.90 | 70.00 | -.067482 |

W = 5.3628E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 2000 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .653 | |
| INLET PRESSURE = | 13.830 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.600 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 146.40 | 30.00 | -.011893 |
| 209.10 | 25.00 | -.008003 |
| 292.70 | 20.00 | -.004136 |
| 376.40 | 15.00 | -.000364 |
| 460.00 | 10.00 | -.044864 |
| 920.00 | 5.00 | -.067677 |
| 1150.10 | 0.00 | -.020570 |
| 1233.70 | 5.00 | .044689 |
| 1212.80 | 10.00 | .060838 |
| 1171.00 | 15.00 | .091021 |
| 1108.20 | 20.00 | .119699 |
| 1024.60 | 25.00 | .150546 |
| 941.00 | 30.00 | .242708 |
| 899.10 | 35.00 | .595518 |
| 815.50 | 40.00 | 4.019160 |
| 731.90 | 45.00 | -.825198 |
| 710.90 | 50.00 | -.216630 |
| 648.20 | 55.00 | -.051727 |
| 585.50 | 60.00 | -.039744 |
| 543.60 | 65.00 | -.037430 |
| 501.80 | 70.00 | -.006873 |

W = 6.3135E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 2400 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.600 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 115.00 | 30.00 | -.036589 |
| 230.00 | 25.00 | -.009021 |
| 276.00 | 20.00 | -.000704 |
| 368.00 | 15.00 | -.003025 |
| 460.00 | 10.00 | -.003049 |
| 552.00 | 5.00 | -.049890 |
| 1035.00 | 0.00 | -.041735 |
| 1196.00 | 5.00 | .050147 |
| 1150.00 | 10.00 | .048720 |
| 1104.00 | 15.00 | .070157 |
| 1012.00 | 20.00 | .085908 |
| 943.00 | 25.00 | .121915 |
| 874.00 | 30.00 | .172394 |
| 828.00 | 35.00 | .300632 |
| 782.00 | 40.00 | .730878 |
| 736.00 | 45.00 | -1.215490 |
| 690.00 | 50.00 | -.279157 |
| 644.00 | 55.00 | -.131274 |
| 598.00 | 60.00 | -.066165 |
| 552.00 | 65.00 | -.025520 |
| 506.00 | 70.00 | .006447 |

W = 6.1472E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 2400 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.100 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 153.40 | 30.00 | -.006188 |
| 204.50 | 25.00 | -.000244 |
| 255.60 | 20.00 | -.004503 |
| 357.80 | 15.00 | -.006299 |
| 460.10 | 10.00 | -.046993 |
| 920.20 | 5.00 | -.067512 |
| 1150.20 | 0.00 | -.025041 |
| 1201.30 | 5.00 | .044931 |
| 1226.90 | 10.00 | .069300 |
| 1175.80 | 15.00 | .078850 |
| 1073.50 | 20.00 | .105690 |
| 1022.40 | 25.00 | .170463 |
| 945.70 | 30.00 | .191796 |
| 843.50 | 35.00 | .258819 |
| 792.40 | 40.00 | 1.274925 |
| 766.80 | 45.00 | -.526701 |
| 715.70 | 50.00 | -.176766 |
| 664.60 | 55.00 | -.132474 |
| 639.00 | 60.00 | -.105843 |
| 613.40 | 65.00 | -.068692 |
| 587.90 | 70.00 | -.045092 |

W = 6.5658E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1200 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 18.000 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 196.00 | 30.00 | -.001893 |
| 247.10 | 25.00 | .001996 |
| 306.70 | 20.00 | .000512 |
| 391.90 | 15.00 | .002432 |
| 460.10 | 10.00 | -.041187 |
| 911.60 | 5.00 | -.055039 |
| 1073.50 | 0.00 | -.008668 |
| 1167.20 | 5.00 | .038457 |
| 1133.20 | 10.00 | .034867 |
| 1013.90 | 15.00 | .036254 |
| 903.10 | 20.00 | .031816 |
| 741.20 | 25.00 | .004983 |
| 587.90 | 30.00 | .006664 |
| 502.70 | 35.00 | .008870 |
| 400.40 | 40.00 | -.002787 |
| 340.80 | 45.00 | .002321 |
| 281.20 | 50.00 | .000450 |
| 247.10 | 55.00 | -.000325 |
| 204.50 | 60.00 | .005701 |
| 196.00 | 65.00 | -.000224 |
| 153.40 | 70.00 | -.044640 |

W = 3.0527E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1200 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 16.900 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 194.70 | 30.00 | .001022 |
| 239.00 | 25.00 | .002111 |
| 300.90 | 20.00 | -.000782 |
| 389.40 | 15.00 | .001508 |
| 460.20 | 10.00 | -.020300 |
| 725.70 | 5.00 | -.037569 |
| 929.30 | 0.00 | -.005190 |
| 1089.00 | 5.00 | .051100 |
| 1106.30 | 10.00 | .048016 |
| 1026.60 | 15.00 | .039404 |
| 885.00 | 20.00 | .029141 |
| 752.30 | 25.00 | .019071 |
| 610.70 | 30.00 | .009826 |
| 513.30 | 35.00 | .007502 |
| 416.00 | 40.00 | .001030 |
| 354.00 | 45.00 | .007192 |
| 300.90 | 50.00 | .001868 |
| 256.70 | 55.00 | -.013842 |
| 203.60 | 60.00 | -.009882 |
| 185.90 | 65.00 | .003757 |
| 159.30 | 70.00 | -.014154 |

W = 3.1166E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1600 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.700 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 177.60 | 30.00 | .000345 |
| 219.40 | 25.00 | -.003209 |
| 303.00 | 20.00 | -.001689 |
| 376.20 | 15.00 | .001067 |
| 459.80 | 10.00 | -.035950 |
| 846.40 | 5.00 | -.054820 |
| 1065.90 | 0.00 | -.010861 |
| 1201.80 | 5.00 | .055853 |
| 1222.70 | 10.00 | .059748 |
| 1139.00 | 15.00 | .056932 |
| 1013.60 | 20.00 | .046694 |
| 856.90 | 25.00 | .026104 |
| 710.60 | 30.00 | .017576 |
| 595.60 | 35.00 | .004490 |
| 480.70 | 40.00 | -.004240 |
| 407.60 | 45.00 | -.002669 |
| 334.40 | 50.00 | -.004761 |
| 292.60 | 55.00 | .003493 |
| 250.80 | 60.00 | -.003820 |
| 219.40 | 65.00 | .003682 |
| 198.60 | 70.00 | .005313 |

1.06 <sup></sup> - .06

W = 3.6641E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1600 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.200 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 180.00 | 30.00 | -.003063 |
| 230.00 | 25.00 | .002441 |
| 280.00 | 20.00 | .000847 |
| 360.00 | 15.00 | -.002884 |
| 460.00 | 10.00 | -.033631 |
| 810.00 | 5.00 | -.049025 |
| 1020.00 | 0.00 | -.010137 |
| 1150.00 | 5.00 | .054807 |
| 1190.00 | 10.00 | .062626 |
| 1120.00 | 15.00 | .063539 |
| 1020.00 | 20.00 | .063998 |
| 890.00 | 25.00 | .049709 |
| 760.00 | 30.00 | .028716 |
| 630.00 | 35.00 | .011479 |
| 530.00 | 40.00 | .011358 |
| 450.00 | 45.00 | .003696 |
| 380.00 | 50.00 | .000826 |
| 330.00 | 55.00 | -.013716 |
| 270.00 | 60.00 | -.006683 |
| 250.00 | 65.00 | .002577 |
| 210.00 | 70.00 | -.039480 |

W = 3.9398E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 2000 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .653 | |
| INLET PRESSURE = | 13.830 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.700 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 175.90 | 30.00 | .000684 |
| 216.50 | 25.00 | -.002831 |
| 297.70 | 20.00 | -.002981 |
| 378.80 | 15.00 | .000449 |
| 460.00 | 10.00 | -.052326 |
| 987.70 | 5.00 | -.074042 |
| 1190.70 | 0.00 | -.003893 |
| 1366.50 | 5.00 | .083952 |
| 1434.20 | 10.00 | .108951 |
| 1393.60 | 15.00 | .115411 |
| 1244.80 | 20.00 | .114136 |
| 1122.90 | 25.00 | .141245 |
| 974.20 | 30.00 | .076527 |
| 811.80 | 35.00 | .003326 |
| 676.50 | 40.00 | -.032650 |
| 554.70 | 45.00 | -.258136 |
| 317.90 | 50.00 | -.054455 |
| 378.80 | 55.00 | .180575 |
| 338.30 | 60.00 | .010591 |
| 297.60 | 65.00 | -.018118 |
| 257.10 | 70.00 | -.043337 |

W = 4.8459E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 2000 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .653 | |
| INLET PRESSURE = | 13.830 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 16.500 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 172.50 | 30.00 | .003046 |
| 207.00 | 25.00 | -.004507 |
| 299.00 | 20.00 | -.002689 |
| 368.00 | 15.00 | .000019 |
| 460.00 | 10.00 | -.043097 |
| 897.00 | 5.00 | -.056746 |
| 1069.50 | 0.00 | -.010708 |
| 1161.50 | 5.00 | .050232 |
| 1196.00 | 10.00 | .064132 |
| 1127.00 | 15.00 | .071573 |
| 1046.50 | 20.00 | .083724 |
| 931.50 | 25.00 | .119023 |
| 908.50 | 30.00 | .188946 |
| 793.50 | 35.00 | -.032448 |
| 586.50 | 40.00 | -.092309 |
| 483.00 | 45.00 | -.010135 |
| 414.00 | 50.00 | .002345 |
| 356.50 | 55.00 | -.016002 |
| 299.00 | 60.00 | -.015946 |
| 264.50 | 65.00 | -.022344 |
| 218.50 | 70.00 | -.057792 |

W = 4.3203E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 2400 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 16.700 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 138.00 | 30.00 | -.005435 |
| 184.00 | 25.00 | -.005686 |
| 260.60 | 20.00 | -.004148 |
| 337.30 | 15.00 | -.006646 |
| 459.90 | 10.00 | -.042119 |
| 858.50 | 5.00 | -.068033 |
| 1165.10 | 0.00 | -.023689 |
| 1303.00 | 5.00 | .070850 |
| 1364.40 | 10.00 | .104720 |
| 1364.40 | 15.00 | .133737 |
| 1257.10 | 20.00 | .130620 |
| 1119.10 | 25.00 | .133012 |
| 981.10 | 30.00 | .103020 |
| 827.80 | 35.00 | -.002612 |
| 674.50 | 40.00 | -.015342 |
| 582.50 | 45.00 | -.021030 |
| 475.20 | 50.00 | -.040809 |
| 413.90 | 55.00 | .013393 |
| 367.90 | 60.00 | .003079 |
| 321.90 | 65.00 | -.002654 |
| 291.30 | 70.00 | .002898 |

W = 5.1617E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 2400 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 15.600 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 209.10 | 30.00 | -.015649 |
| 292.70 | 25.00 | -.009178 |
| 397.30 | 20.00 | .010672 |
| 418.20 | 15.00 | .016338 |
| 460.00 | 10.00 | -.081119 |
| 1275.50 | 5.00 | -.143652 |
| 1568.20 | 0.00 | -.015772 |
| 1777.40 | 5.00 | .145599 |
| 1840.10 | 10.00 | .235334 |
| 1819.20 | 15.00 | .534068 |
| 1735.50 | 20.00 | -3.451748 |
| 1610.10 | 25.00 | -.301028 |
| 1421.90 | 30.00 | -.132751 |
| 1275.50 | 35.00 | -.078483 |
| 1129.10 | 40.00 | -.020268 |
| 982.80 | 45.00 | .013157 |
| 857.30 | 50.00 | .042214 |
| 731.80 | 55.00 | .028762 |
| 669.10 | 60.00 | -.033867 |
| 627.30 | 65.00 | -.008101 |
| 564.60 | 70.00 | .040362 |

W = 8.4280E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1200 RPM, DF-2 FUE

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.600 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 197.20 | 30.00 | .000115 |
| 244.10 | 25.00 | .003113 |
| 300.50 | 20.00 | .002136 |
| 375.60 | 15.00 | .000701 |
| 460.10 | 10.00 | -.008724 |
| 610.40 | 5.00 | -.025767 |
| 816.40 | 0.00 | -.006291 |
| 967.20 | 5.00 | .047784 |
| 1014.10 | 10.00 | .053649 |
| 986.00 | 15.00 | .054860 |
| 892.10 | 20.00 | .049523 |
| 788.80 | 25.00 | .040440 |
| 666.70 | 30.00 | .024433 |
| 563.40 | 35.00 | .015483 |
| 469.50 | 40.00 | .005583 |
| 394.40 | 45.00 | -.006842 |
| 319.30 | 50.00 | -.011776 |
| 272.30 | 55.00 | .006067 |
| 244.10 | 60.00 | .002156 |
| 206.60 | 65.00 | -.020977 |
| 169.00 | 70.00 | -.034391 |

W = 3.3447E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1200 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .700 | |
| INLET PRESSURE = | 13.910 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 15.100 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (P S I) | THETA (D E G) | DQ/DTHETA |
|---|---|---|
| 204.40 | 30.00 | .008194 |
| 235.10 | 25.00 | .002505 |
| 306.60 | 20.00 | -.000834 |
| 388.40 | 15.00 | .002230 |
| 460.00 | 10.00 | -.009935 |
| 633.60 | 5.00 | -.025734 |
| 817.60 | 0.00 | -.005738 |
| 950.50 | 5.00 | .050668 |
| 1042.40 | 10.00 | .065288 |
| 1027.00 | 15.00 | .066185 |
| 950.50 | 20.00 | .061186 |
| 838.00 | 25.00 | .050140 |
| 725.60 | 30.00 | .050630 |
| 643.90 | 35.00 | .035888 |
| 531.40 | 40.00 | .002534 |
| 449.80 | 45.00 | .009703 |
| 388.40 | 50.00 | -.008077 |
| 316.80 | 55.00 | -.016942 |
| 276.00 | 60.00 | -.006424 |
| 235.10 | 65.00 | -.013339 |
| 204.40 | 70.00 | -.016145 |

W = 3.7701E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1600 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 17.200 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 200.40 | 30.00 | .005634 |
| 235.80 | 25.00 | .004015 |
| 294.80 | 20.00 | .001956 |
| 365.60 | 15.00 | -.000632 |
| 460.00 | 10.00 | -.011678 |
| 624.90 | 5.00 | -.026955 |
| 825.30 | 0.00 | -.002689 |
| 1002.20 | 5.00 | .055724 |
| 1061.10 | 10.00 | .065670 |
| 1061.10 | 15.00 | .077550 |
| 990.80 | 20.00 | .081388 |
| 907.80 | 25.00 | .078556 |
| 789.90 | 30.00 | .055859 |
| 683.80 | 35.00 | .045853 |
| 589.50 | 40.00 | .031615 |
| 507.00 | 45.00 | .004835 |
| 424.40 | 50.00 | .002608 |
| 377.30 | 55.00 | .001945 |
| 318.30 | 60.00 | -.013665 |
| 283.00 | 65.00 | -.003069 |
| 247.60 | 70.00 | -.024261 |

W = 4.2309E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1600 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .672 | |
| INLET PRESSURE = | 13.870 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.200 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P. ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 184.00 | 30.00 | .002074 |
| 223.40 | 25.00 | .003334 |
| 276.00 | 20.00 | -.003740 |
| 381.10 | 15.00 | -.002296 |
| 460.00 | 10.00 | -.012128 |
| 644.00 | 5.00 | -.028652 |
| 841.00 | 0.00 | -.006078 |
| 985.50 | 5.00 | .048221 |
| 1024.90 | 10.00 | .059586 |
| 1024.90 | 15.00 | .082306 |
| 998.60 | 20.00 | .102630 |
| 933.00 | 25.00 | .106501 |
| 841.00 | 30.00 | .100484 |
| 749.00 | 35.00 | .078640 |
| 643.90 | 40.00 | .078609 |
| 591.30 | 45.00 | .055937 |
| 486.20 | 50.00 | -.018779 |
| 433.60 | 55.00 | .002182 |
| 368.00 | 60.00 | -.021692 |
| 328.60 | 65.00 | .024427 |
| 302.30 | 70.00 | .030580 |

W = 4.6714E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2000 RPM, DF-2 FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .653 | |
| INLET PRESSURE = | 13.830 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 14.800 | |
| FUEL MOLECULAR WT = | 184.000 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P ( P S I ) | THETA ( D E G ) | DQ/DTHETA |
|---|---|---|
| 147.90 | 30.00 | -.005934 |
| 197.20 | 25.00 | -.003224 |
| 262.90 | 20.00 | -.003161 |
| 345.00 | 15.00 | -.005990 |
| 460.00 | 10.00 | -.021793 |
| 690.10 | 5.00 | -.047142 |
| 1002.20 | 0.00 | -.023167 |
| 1133.70 | 5.00 | .052024 |
| 1150.10 | 10.00 | .060052 |
| 1100.80 | 15.00 | .083991 |
| 1068.00 | 20.00 | .135668 |
| 1035.10 | 25.00 | .197913 |
| 969.40 | 30.00 | .261350 |
| 887.20 | 35.00 | .443169 |
| 821.50 | 40.00 | -203.549418 |
| 722.90 | 45.00 | -.721925 |
| 673.60 | 50.00 | -.217097 |
| 607.90 | 55.00 | -.046813 |
| 542.20 | 60.00 | .033528 |
| 476.50 | 65.00 | .003508 |
| 443.60 | 70.00 | -.055622 |

W = 6.0422E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2000 RPM, 8CM FUEL

| | | | |
|---|---|---|---|
| BORE DIAMETER | = | 3.800 | INCHES |
| CRANK RADIUS | = | 1.875 | INCHES |
| CONNECTING ROD LENGTH | = | 6.375 | INCHES |
| COMPRESSION RATIO | = | 16.700 | |
| VOLUMETRIC EFFICIENCY | = | .653 | |
| INLET PRESSURE | = | 13.830 | PSI |
| INLET TEMPERATURE | = | 560.000 | DEG. R |
| AIR/FUEL RATIO | = | 12.300 | |
| FUEL MOLECULAR WT | = | 181.200 | LB/LB-MOLE |
| SF1 | = | 0.000 | |
| SF2 | = | 1.000 | |
| PATM | = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 162.40 | 30.00 | -.006672 |
| 216.50 | 25.00 | -.000321 |
| 270.60 | 20.00 | -.000696 |
| 351.80 | 15.00 | -.004644 |
| 460.00 | 10.00 | -.032087 |
| 784.70 | 5.00 | -.046097 |
| 987.70 | 0.00 | -.010391 |
| 1109.50 | 5.00 | .053112 |
| 1150.00 | 10.00 | .066611 |
| 1109.50 | 15.00 | .076715 |
| 1028.30 | 20.00 | .082993 |
| 920.00 | 25.00 | .074469 |
| 798.30 | 30.00 | .050673 |
| 676.50 | 35.00 | .044098 |
| 595.30 | 40.00 | .050211 |
| 514.10 | 45.00 | .025192 |
| 446.50 | 50.00 | .000676 |
| 378.80 | 55.00 | -.002356 |
| 338.20 | 60.00 | -.012809 |
| 284.10 | 65.00 | -.021523 |
| 257.10 | 70.00 | .004467 |

W = 4.3553E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2400 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 13.000 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 131.40 | 30.00 | -.023869 |
| 219.00 | 25.00 | -.004421 |
| 262.80 | 20.00 | -.000638 |
| 350.40 | 15.00 | -.005727 |
| 460.00 | 10.00 | -.035140 |
| 810.30 | 5.00 | -.048415 |
| 1007.40 | 0.00 | -.011277 |
| 1116.90 | 5.00 | .048664 |
| 1138.80 | 10.00 | .064940 |
| 1116.90 | 15.00 | .101492 |
| 1116.90 | 20.00 | .153665 |
| 1051.20 | 25.00 | .189940 |
| 985.50 | 30.00 | .312457 |
| 919.80 | 35.00 | .833055 |
| 854.10 | 40.00 | -1.086248 |
| 810.30 | 45.00 | -.290657 |
| 766.50 | 50.00 | -.115697 |
| 700.80 | 55.00 | -.035681 |
| 635.10 | 60.00 | .001283 |
| 569.40 | 65.00 | .068148 |
| 481.80 | 70.00 | .190884 |

W = 6.5939E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2400 RPM, BCM FUEL

| | | |
|---|---|---|
| BORE DIAMETER = | 3.800 | INCHES |
| CRANK RADIUS = | 1.875 | INCHES |
| CONNECTING ROD LENGTH = | 6.375 | INCHES |
| COMPRESSION RATIO = | 16.700 | |
| VOLUMETRIC EFFICIENCY = | .659 | |
| INLET PRESSURE = | 13.790 | PSI |
| INLET TEMPERATURE = | 560.000 | DEG. R |
| AIR/FUEL RATIO = | 11.300 | |
| FUEL MOLECULAR WT = | 181.200 | LB/LB-MOLE |
| SF1 = | 0.000 | |
| SF2 = | 1.000 | |
| PATM = | 0.000 | |

| P (PSI) | THETA (DEG) | DQ/DTHETA |
|---|---|---|
| 57.50 | 30.00 | -.011651 |
| 103.50 | 25.00 | -.002674 |
| 126.50 | 20.00 | -.002335 |
| 184.00 | 15.00 | -.003802 |
| 241.50 | 10.00 | -.022343 |
| 483.00 | 5.00 | -.024902 |
| 575.00 | 0.00 | -.003554 |
| 632.50 | 5.00 | .018418 |
| 621.00 | 10.00 | .023632 |
| 609.50 | 15.00 | .034969 |
| 586.50 | 20.00 | .042382 |
| 552.00 | 25.00 | .042176 |
| 444.50 | 30.00 | .045939 |
| 471.50 | 35.00 | .055685 |
| 425.50 | 40.00 | .039543 |
| 379.50 | 45.00 | .036449 |
| 345.00 | 50.00 | .035551 |
| 310.50 | 55.00 | .022460 |
| 276.00 | 60.00 | .006135 |
| 241.50 | 65.00 | -.025882 |
| 195.50 | 70.00 | -.056[illegible] |

W = 3.1148E+02

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